BLM LIBRARY
88018875

Third National MOSS Users Workshop

June 2-5, 1986

Fort Collins, Colorado

March 3, 1849

United States Department of the Interior

BUREAU OF LAND MANAGEMENT
DENVER SERVICE CENTER
DENVER FEDERAL CENTER, BUILDING 50
P.O. BOX 25047
DENVER, COLORADO 80225-0047

IN REPLY
REFER TO:

Dear Participants:

At long last....!

These proceedings officially record many of the new applications and developments identified during the Third National MOSS Users Workshop, June 2-5, 1986. Papers and abstracts are reprinted verbatim; none have been edited .

We wish to thank all of you for making our workshop a success and we look forward to your continued participation at the Fourth National MOSS Users Workshop, scheduled the week of May 18, 1987, in Denver.

If you have any questions about the 1986 or 1987 workshops, feel free to contact William J. Bonner, Bureau of Indian Affairs, FTS 776-~~2224~~ 2250 or (303) 236-2224.

Again, thank you all for your significant contributions!

Robert R. Ader
FTS 776-0089 or (303) 236-0089

Tracey R. Feagan
FTS 776-4242 or (303) 236-4242

Janet J. Poorman
FTS 776-0104 or (303) 236-0104

20937745
ID88018875

BLM LIBRARY
SC-324A, BLDG. 50
DENVER FEDERAL CENTER
P. O. BOX 25047
DENVER, CO 80225-0047

QA
76.9
.M91
M677
1986
c.2

Proceedings

Third National MOSS Users Workshop

Compiled By

U.S. Department of the Interior
Bureau of Land Management
Denver, Colorado 80225-0047

U.S. Department of the Interior
Fish and Wildlife Service
Fort Collins, Colorado 80526-2899

and

TGS Technology, Inc.
P.O. Box 28J, Station 16
Lakewood, Colorado 80228

January 1987

ACKNOWLEDGMENTS

The success of the Third National MOSS Users Workshop resulted from the combined efforts of many agencies and individuals. We believe the Workshop and Proceedings represent a significant contribution toward the awareness and development of the MOSS family of software.

We especially acknowledge and thank Ralph Marker, Chief, Division of Advanced Data Technology (retired), and Tracey R. Feagan, Workshop Coordinator, TGS Technology, Inc., for their tireless, unrelenting efforts toward making the conference a total success.

We also thank the following individual members of the Workshop Planning Committee who significantly contributed their time and expertise:

- Robert Ader, Branch Chief, Technology Applications Assistance, BLM
- Duane Asherin, Group Leader, Rapid Assessment Methods Group, U. S. Fish and Wildlife Service
- William J. Bonner, National GIS Coordinator, Bureau of Indian Affairs
- Edward Chapman, GIS Coordinator, Soil Conservation Service
- Barbara J. Duggan, Data Analyst, TGS Technology, Inc., BLM Operations
- Don Hunter, Ecologist, Rapid Assessment Methods Group, Fish and Wildlife Service
- Jill Lancaster, CSU Conference Coordinator, CSU/BLM
- H. Dennison Parker, Coordinator of GIS Technology, College of Forestry and Natural Resources, CSU/BLM
- Elizabeth Porter, Physical Scientist, COE/ETL
- Wayne Rohde, Chief, Spatial data Technology Office, U. S. Geological Survey
- Barbara White, Computer Specialist, Fish and Wildlife Service

In addition, we gratefully acknowledge our sponsors, who provided qualified personnel and quality facilities and resources:

U. S. Department of the Interior
  Bureau of Land Management
  Fish and Wildlife Service
    Research and Development Program
    Division of Biological Services
  Bureau of Indian Affairs
    Office of Trust Responsibilities
  Geological Survey/National Mapping Division

U.S. Army Engineer Topographic Laboratories (ETL)
U.S. Department of Agriculture
  Soil Conservation Service
Colorado State University
  Office of Conference Services
TGS Technology, Inc.
  BLM Operations

And lastly, we thank you, our participants, for your enthusiasm and continued support.

CONTENTS

Page

INTRODUCTION 1

COOPERATIVE STRATEGY PRESENTATIONS

GIS Implementation Status 5
FICCDC Standards Committee Report 7
Individual Agency Reports 9

APPLICATION PRESENTATIONS

Geographic Analysis of Alaska's National Wildlife Refuges 25
Applications of a Geographic Information System to Wildlife Management on Public Lands in Wyoming 37
Use of Geographic Information Systems to Analyze Impacts of CO_2 Gas Development on Elk Calving Areas . . . . 45 ✓
Geographic Reference and Information Database--Central Arizona Project 57
Integration of a Relational Database Management System with MOSS 65
Some Capabilities of MOSS/MAPS Applied to Cultural Resource Management 71
Modeling Narcotic Crop-Growing Sites with MOSS 83
Map Overlay and Statistical System Terrain Data Handling Capability 97
GIS Training in the Professional Setting: Requirements for a Successful Training Session 109

SYSTEMS PRESENTATIONS

Central Arizona Project High Accuracy Digital Data Bases 119
Rendering MOSS and MAPS Data Using Modern 3-D Display Techniques 125
A Controlled Study of Some Two-Dimensional Interpolation Methods 133
MOSS Family Software Development Issues . . . . 149 ✓ Topological relationship std
The MOSS Family in the VAX Environment 161
The Terrain Analyst Work Station 169
Recent Enhancements to the GRID Command 177
Use of MOSS in the Coastal Zone Permitting Process 187

POSTER PRESENTATIONS

A Comparison of Graphic Output MOSS: COS 3 vs MOSS 191
Regression Models for Predicting AMS Digitizing Times for Land Resource Maps 193
Applications of VAX/MOSS with Large Data Sets 195
The Applications of GIS Technology to Wetland Mapping in Delaware 197
Expert System Interface with MOSS 199
Generating MTPS with ADS 201
A Microcomputer Geographic Information System Workstation 203

WORK GROUP SUMMATIONS

Management Work Group Summation 207
Systems Work Group Summation 211

APPENDIXES

Appendix A - List of Workshop Participants 221
Appendix B - Workshop Evaluation 229

CONTENTS

Page

INTRODUCTION . . . 1

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

APPENDICES

[illegible]

INTRODUCTION

The Third National MOSS (Map Overlay and Statistical System) Users Workshop was held at Colorado State University, Fort Collins, June 2-5, 1986. The workshop had a paid attendance of 154 (Appendix A), representing personnel from all levels of management, applications, and systems development within federal and state agencies, as well as some universities and private organizations.

The objectives of the workshop were to provide a forum to . . .

- o enhance interagency communication for the use, maintenance, and development of the MOSS family of software (ADS, AMS, MOSS, MAPS, COS);
- o discuss enhancements implemented during the last year;
- o identify research and development needs;
- o continue coordinating future software applications, maintenance, and development; and
- o present techniques, strategies, and mechanisms for the use, development, and management of the MOSS family of software and related hardware/software technology.

These objectives were integrated throughout the following workshop activities, from the presentations through the subgroup concerns:

Monday, June 2	Cooperative Strategy Presentations
Tuesday, June 3	Applications and Systems Presentations
Wednesday, June 4	o Poster Session Presentations (unstructured/informal) o Subgroup Work Sessions for Managers, Users, and Systems Personnel
Thursday, June 5	o Continuation of Subgroup Work Sessions o Summaries

Comments about the workshop are summarized in Appendix B, Workshop Evaluation.

Cooperative Strategy

Presentations

GIS IMPLEMENTATION STATUS

by

Eric Strand
Bureau of Land Management
Branch of GIS Development
Building 50, Service Center
Denver, Colorado 80225-0047
Telephone: (303) 236-0103

I appreciate the opportunity to comment on the status of GIS implementation. After a few remarks on GIS implementation in general, I will describe the status of GIS implementation in the Bureau of Land Management (BLM).

Whoever coined the term, "The Information Age," was thinking that computers would revolutionize the way we do things. Most of us here believe the implementation of GIS technology will revolutionize natural resource management and here we are in June of 1986, 1-1/2 years after the last MOSS Users Workshop held in January 1985. I would not characterize the last 18 months as making revolutionary progress in GIS implementation, but rather as progress through evolution (and at times convolution).

GIS continues to receive increased attention in both the public and private sectors. This is evident by the recent number of conferences held on GIS; by the number of universities beginning to include GIS and related topics in curricula; by the advent of new technologies for automated mapping, scan digitizing, graphics work stations; and by the number of emergent companies pursuing a share of the GIS market place.

Several departments of the Federal Government are very active in GIS development and implementation. Defense is looking at the "automated battlefields" of the future; Agriculture is completing a user requirements study for the Forest Service; Interior has several agencies represented within the Co-op Strategy Group, is pursuing a consolidated GIS computer procurement, has contracted a study by MITRE to provide input for GIS policy development, and has maintained the Interior Digital Cartographic Coordinating Committee and various working groups.

What does GIS implementation take to put into practice new methodology using the tools automation can provide? We look at the status of GIS implementation in terms of training people in GIS technology and application; creating and maintaining coordination groups, pursuing new applications, and improving existing ones; acquiring the needed computer power and user work stations (digitizers, plotters, terminals); obtaining the necessary software (maintaining, enhancing, developing new capabilities); constructing the required digital data bases by digitizing maps, purchasing, or trading available digital data; as well as developing, promoting, revising, and instituting standards for exchanging and managing data and data processing technology.

In BLM we have trained over 360 people from various disciplines, the Phoenix Training Center is coordinating with the Service Center on training needs assessment; we are participating in the DOI GIS computer procurement; we have maintained the established GIS coordinators network in State Offices and they have actively engaged in technology transfer to District and Resource Area Offices; we have active User Advisory Networks for wildlife, range, and minerals interests. All of the BLM State Offices (except the Eastern States Office) have ongoing GIS activities. These include Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, and Wyoming. The Washington Office has also been actively supporting GIS implementation: the Director of BLM has issued a policy statement for GIS; a Spatial System advisory team was established to coordinate implementation issues; and a Decision Framework Document was developed to address these issues; our Information Resource Management group has been conducting a Bureau Modernization Study; they are currently negotiating with American Management Systems to include GIS requirements in the ongoing Bureau Modernization Study and to prepare for Life Cycle Management (which is currently descending on GIS from Interior).

In conclusion, GIS implementation is moving forward in BLM and other agencies, primarily through the collective efforts of dedicated individuals.

FICCDC STANDARDS COMMITTEE REPORT

Title U.S Federal Agency Progress Towards the Development of Digital Cartography Data Exchange Standards

Author(s) Gale W. TeSelle

Affiliation U.S. Department of Agriculture - Soil Conservation Service

U.S. Federal Agency Progress Towards the Development of Digital Cartography Data Exchange Standards

A draft digital cartography data exchange format standard has been developed by the Standards Working Group of the Federal Interagency Coordinating Committee on Digital Cartography (FICCDC). The FICCDC was created as a result of the United States Office of Management and Budget (OMB) memorandum to the U.S. Geological Survey (USGS) in April 1983. The Standards Working Group (SWG) was formed by the FICCDC steering committee to "develop and adopt, for use by all federal agencies, common standards of content, format, and accuracy for digital cartographic data bases, to increase its interchangeability and enhance its potential for multiple use." Ten federal agencies are participating in the SWG effort.

The process of developing a proposed federal standard for exchanging digital cartographic data began with an identification of existing federal agency digital cartographic data exchange formats. Ten federal agency exchange formats were selected for review. After review, the SWG concluded that no existing federal agency exchange formats contained all the components necessary to efficiently exchange federal agency digital cartographic data.

Over a one year period the SWG developed a draft digital cartographic data exchange format which hopefully incorporates the characteristics needed to standardize the exchange of U.S. federal agency digital cartographic data. The draft format is being reviewed by some 27 federal agencies involved in exchanging digital cartographic data. Tests are being conducted regarding the actual exchange of data using the new format to assist in evaluating the draft standard and determining the feasibility of use in the federal government.

The draft standard format includes specifications for exchanging point, line, polygon, gridded data, and associated attributes as well as features, which can be combinations of the four previous types. The format is characterized by the use of free field formats separated by delimiters and special symbols. Currently the exchange format is only defined for magnetic tape medium. Copies of the digital cartography data exchange format are available upon request. This work is being done in coordination with the National Committee on Digital Cartographic Data Standards.

INDIVIDUAL AGENCY REPORTS

GEOGRAPHIC INFORMATION SYSTEMS

by

David A. Nystrom
National Mapping Division
U.S. Geological Survey
Reston, Virginia 22092
Telephone: 648-4505

A geographic information system (GIS) is a computer hardware and software system designed to collect, manage, analyze and display spatially referenced data. Geographic information systems are emerging as the major spatial data handling tools for solving complex natural resource planning problems. The use of GIS technology has revolutionary implications for the way the U.S. Geological Survey, State, and other Federal agencies conduct research and present research results. Advanced GIS technologies have the potential to greatly enhance the Survey's ability to perform its traditional missions of earth science data collection, research, and information delivery.

At the present time, four USGS divisions are actively involved in GIS activities.

a. The Information Systems Division is supporting the operating divisions by assessing advanced hardware capabilities, assessing GIS applications on microcomputers, development of an Earth Science Information Network, development of an Earth Science Data Directory, and investigating the feasibility of combining artificial intelligence with existing GIS capabilities.

b. The Geologic Division is using GIS as a tool for geologic/geographic information management and computer mapping capabilities.

c. The Water Resources Division is using GIS for the analysis and production of hydrologic data bases and is the largest user of GIS in the Survey from a programmatic standpoint.

d. The National Mapping Division (NMD) is concentrating on basic GIS research activities including; spatial data base design, modeling of cartographic activities and objects, prototype spatial operator implementation, GIS evaluations, and vector data interface capabilities. Also, NMD is working with other divisions, bureaus, and Federal and State agencies on a wide range of cooperative GIS projects.

DIGITAL CARTOGRAPHIC DATA

Submitted by

Claude Christensen
U. S. Fish and Wildlife Service
Office of Information Resource Management
18th and C Streets NW
Washington, D.C. 20240
Telephone: (202) 653-7498

Applications of digital cartographic data include fish and wildlife species analysis and modeling habitat suitability determinations; national wetlands inventory; energy development assessment; coal and oil shale management; forest pest management and impact assessment; refuge-wide vegetation/terrain mapping and land records information management. Comprehensive, site-specific and regional data bases are constructed which often include the following types of digital data; public land survey, transportation, hydrography, political and administrative boundaries, topography, land use, vegetation type, soil type, soil salinity, sedimentation, fish and wildlife species distribution, bathymetry, water quality, mineral and mineral fuel deposits, and wildlife habitat characteristics. These data are digitized, merged, and integrated into multilayered data bases and analyzed by using specific GIS technology such as the Service-developed Map Overlay and Statistical System (MOSS) family of software to perform national wildlife refuge resource assessment and management functions, portray conflicts in the use of the land, perform wildlife habitat suitability mapping, monitor changes in wetlands, and prepare coordination act reports and environmental/impact statements.

The Fish and Wildlife Service also conducts developmental activities in support of GIS tools and technologies, and is a major intra- and interdepartmental cooperator in GIS applications relating to natural resource management.

August 31, 1986

STATUS REPORT
ON
SOIL CONSERVATION SERVICE
GEOGRAPHIC INFORMATION SYSTEM (SCS) ACTIVITIES

United States Department of Agriculture
Soil Conservation Service
Cartography and Geographic Information Systems Division
Washington, D. C. 20013

Background

Since 1982, SCS has initiated and partially funded several GIS related projects in direct support of on-going SCS state and county functional activities. To date, SCS has depended on universities and other government agencies for GIS hardware and software support. However, plans are under way to install and operate GIS hardware and software within SCS. This report provides a status summary of SCS GIS related activities in both the micro and minicomputer arena.

Microcomputer GIS Activities

In September of 1985, SCS awarded the Field Office Communication and Automation System (FOCAS) microcomputer contract. This contract provides SCS staffs the opportunity to procure AT&T 3B2, 400 central processing units, PC-6300 intelligent workstations, and graphic support hardware. This equipment, which supports the Unix operating system provides the capability for implementing GIS technology within SCS field offices.

SCS has identified two Unix based, public domain software packages, which if converted to run on the AT&T equipment, show excellent promise in satisfying SCS field office GIS needs. These two packages are the Map Overlay and Statistical System (MOSS) (which is supported by the Map Analysis Package System (MAPS), and Analytical Mapping System (AMS) software), and the Geographic Resource Analysis Support System (GRASS). Funding has been identified and approvals obtained to convert these two software packages to the AT&T environment and to pilot test the software in six SCS field offices. The following two SCS plans have been developed in support of this activity:

- Development Plan for Pilot Testing and Implementing GIS Software on FOCAS Hardware
- SCS FOCAS Based GIS Pilot Test Plan

On March 14, 1986, SCS entered into a cooperative agreement with the U. S. Army Construction Engineer Research Laboratory (CERL) to convert, enhance, and develop their GRASS software for operation in the SCS FOCAS environment. SCS plans to use this raster based, menu driven GIS as the core software on which to pilot test.

In May, 1986, SCS placed a request for proposals (RFP) in the Commerce Business Daily to convert the MOSS/MAPS/AMS family of GIS software to run on the AT&T equipment. Four vendors have responded with proposals. SCS is presently reviewing the proposals and plans to award a contract in late August, 1986. Software modules from the MOSS family will be evaluated and where feasible used to provide vector analysis capabilities to the core GRASS package.

SCS plans to test and evaluate the GRASS software on FOCAS in supporting the following SCS applications:

- soil map digitizing
- county or parish soil interpretative map production
- farm, ranch, and small watershed interpretative maps and analysis, and
- GIS integration with the SCS Computer Assisted Management and Planning System (CAMPS) software.

The six SCS sites which have been selected for pilot testing the GRASS software are:

- Prosser, Washington - Field office (Benton County)
- Greeley, Colorado - Area Office (Weld County)
- Columbia, Missouri - State Office
- Stillwater, Oklahoma - State Office
- Albany, New york - Area Office (Rensselaer County)
- Winooski, Vermont - Field Office (Franklin County)

Delivery of the software to SCS is staged starting in October 1986 with final delivery scheduled for April 1987. System installation and training for the pilot test sites is scheduled for June 1987 with testing to be completed by October 1987. If the pilot test projects prove successful, broader SCS use and support for the GRASS GIS software could begin in January 1988.

SCS county and area offices will be able to use the FOCAS microcomputers to access the SCS state office minicomputers, when and if installed, and/or state agency computers to satisfy their need for data from state and national resource data bases.

SCS is also evaluating a commercial microcomputer based software package. In early 1985, the agency funded the acquisition of both hardware and a commercially available GIS software package (Aeronca, AE-GIS) for installation on a microcomputer in the Vermont state office. The study plan calls for testing AE-GIS software in supporting the following conservation planning activities: waste management plans and maps, soil interpretation maps, location of installed practices by land use, acreage summaries and maps in support of Vermont land use and development law, identification of flood plains and wetlands and print/plot conservation plan maps. This effort will result in user test and evaluation reports that identify the type of hardware and software required to support specific applications. This and other related information will be used to drive SCS development activities in the public domain microcomputer based GIS arena. Completion of this commercial GIS pilot project is scheduled for December 31, 1986.

In late August, 1986, SCS plans to install and demonstrate the GeoBased commercial GIS software on FOCAS equipment in Henderson County, North Carolina. The software will be procured by the local Soil and Water Conservation District using funds provided by TVA. This TVA/SCS cooperative project is supported by the Soil and Water 201 Program.

Minicomputer GIS Activities

As an initial effort, to implement information management systems (hardware and software within SCS, the agency recently procured three Data General MV/8000 II minicomputers and additional peripheral hardware e.g., plotters, graphic terminals, digitizers, disk storage, etc. This hardware has been installed in three separate SCS offices - National Headquarters (NHQ), Washington, D.C.; West National Technical Center (WNTC), Portland, Oregon; and the California state office in Davis. During a two year pilot test period, these computers and software will be evaluated as to how well they support all SCS application needs. This effort is expected to result in user tests and evaluation reports that identify the type of hardware and software required to support specific application areas, and benefits SCS can expect to derive. This evaluation information will be used to decide on a national SCS minicomputer procurement action planned in FY 88-89.

GIS applications represent one of several application areas scheduled for test and evaluation. The agency has selected MOSS/MAPS/AMS/COS as the GIS and related software to be implemented, tested and evaluated during the two year pilot study period. These GIS software packages were selected because they are public domain systems that are not restricted by proprietory license fees or a lengthy competitive procurement process.

In September 1985, SCS awarded Autometrics, Inc., a contract to implement the most recent versions of the MOSS/MAPS/AMS/COS software at all three SCS, GIS test sites. This contractor was also funded to provide training on the use of the MOSS/MAPS software and provide one year of software maintenance for each site. SCS also established a cooperative agreement with the Fish and Wildlife Service (FWS) to provide training on the use of the AMS and COS software.

To date, Autometric has installed all the GIS software packages and provided MOSS/MAPS training at all three test sites. Selected personnel from NHQ and the California state office have attended AMS and COS training at the FWS office in Ft. Collins, Colorado.

MOSS will be evaluated as to how well it supports conservation planning, use of soils data and resource inventory activities at the state and county levels. At the national level, the integration of Natural Resource Inventory (NRI) and Major Land Resource Area (MLRA) data will be evaluated. Some specific applications will be evaluated such as identification of potential soil salinity areas.

A national SCS, GIS technical team will be formed and will meet several times during the GIS pilot study to prepare detailed GIS procurement information. This information will be used in an overall procurement document which will contain the basic needs, workload analysis, office impact, cost benefit analysis and detailed hardware and software specifications required to support the SCS national minicomputer hardware and GIS software procurement action.

As mentioned earlier in this report, SCS has also initiated and partially funded several minicomputer GIS projects in direct support of on-going SCS state and county functional activities. These projects involve many of the more widely used GISs, e.g., ARC/INFO, INTERGRAPH, COMARC, MOSS, and ODYSSEY. Appendix A of this report, provides a list of SCS state offices which are participating in the use of these systems. These activites are being supported through the use of cooperative agreements with other state or federal agencies.

GIS Coordination

SCS has established national headquarters, national technical center, and state office GIS coordinators in order to better coordinate the many on-going GIS related activities within the agency. In addition, SCS has personnel supporting two interagency coordinating committees, the Federal Interagency Coordinating Committee on Digital Cartography (FICCDC) and the MOSS Cooperative Strategy Committee.

Appendix B of this report is a list of SCS technical papers pertaining to geographic information systems. If interested, please contact Ed Chapman, SCS, National GIS Coordinator, on FTS 447-5381 or (202) 447-5381, for additional information.

ATTACHMENT A

SCS STATE OFFICE MINICOMPUTER-BASED GIS ACTIVITIES SUPPORTED BY COOPERATIVE AGREEMENTS WITH STATE OR FEDERAL AGENCIES

o ARC/INFO (Commercial)

SCS St. Office	Cooperator	System
Arizona	Arizona St. Lands Dept.	Prime-9955
Connecticut	St. Dept. of Environmental Protection	DG-MV10000
Kentucky	St. Dept. of Natural Resources	Prime-750
Minnesota	Minnesota St. Planning Agency	Prime-850
Rhode Island	University of Rhode Island	Prime-9955
Vermont	University of Vermont	VAX-750
Washington	St. Dept. of Natural Resources	Prime-750
Utah	Utah Auto. Geographic Reference St. Dept. of Agriculture	Prime-550

o INTERGRAPH (Commercial)

SCS St. Office	Cooperator	System
Florida	St. Dept. of Transportation	VAX
Michigan	St. Dept. of Transportation St. Dept. of Natural Resources	VAX
Tennessee	Tennessee Valley Authority	VAX
Virginia	Tennessee Valley Authority	VAX

o MOSS (Public domain)

SCS St. Office	Cooperator	System
Arizona	Bureau of Land Management	DG
Colorado	Fish and Wildlife Service	DG
Idaho	Bureau of Land Management	DG-MV10000
Missouri	University of Missouri	VAX-750

o COMARC (Commercial)

SCS St. Office	Cooperator	System
North Carolina	St. Dept. of Natural Resources	DG

o ODESSEY (Public domain)

SCS St. Office	Cooperator	System
Wisconsin	University of Wisconsin	VAX-780

July 1986
CGIS Division

ATTACHMENT B

SCS Technical Papers pertaining to Geographic Information Systems (GIS)

1. TECHNICAL SPECIFICATIONS FOR LINE-SEGMENT DIGITIZING OF DETAILED SOIL SURVEY MAPS; G. TeSelle, R. Glenn, S. Jordan; SCS, Cartography & GIS Division, Washington, D.C.; September 1984; 13 pages; the specifications used by SCS to contract for this digitizing service.

2. TECHNICAL SPECIFICATIONS FOR LINE-SEGMENT DIGITIZING OF 1:100,000 SCALE LAND-USE MAPS; R. Glenn, S. Jordan; SCS, Cartography & GIS Division, Washington, D.C.; August 1984; 11 pages; the specifications used by SCS to contract for this digitizing service.

3. SCS TECHNICAL SPECIFICATIONS FOR LINE-SEGMENT DIGITIZING AT 1:250,000 SCALE GENERAL SOIL MAPS: R. Glenn, S. Jordan; SCS, Cartography & GIS Division, Washington, D.C.,; March 1985; 12 pages; the specifications used by SCS to contract for this digitizing service.

4. SCS GEOGRAPHIC EXCHANGE FORMAT - STANDARD VERSION; R. Glenn; SCS, Cartography & GIS Division, Washington, D.C.; October 1982; 4 pages; the format, structure and standards of magnetic tapes prepared by SCS for soil graphics transfer.

5. GEOGRAPHIC EXCHANGE FORMAT - OPTIONAL VERSION; R. Glenn; SCS, Cartography & GIS Division, Washington, D.C.; September 30, 1984; 5 pages; improved specifications for the format, structure and standards of magnetic tapes prepared by SCS for soil graphics transfer (supersedes the standard version).

6. SCS SOIL MAP DIGITIZING STANDARD AND GEOGRAPHIC EXCHANGE FORMAT; G. TeSelle; SCS, Cartography & GIS Division, Washington, D.C.; June 10, 1985; 2 pages; a brief summary of the digitizing and data base aspects of the Geographic Exchange Format - Optional Version (September 30, 1984).

7. BUILDING A MODERN NATIONAL SOIL DATA BASE - IMPLICATIONS TO LOCAL GOVERNMENT; G. TeSelle, G. Decker, K. Young; SCS, Washington, D.C.; April, 1984; 7 pages; published in the Wisconsin Land Information Reports, Number 1; Seminar on the Multipurpose Cadastre: Modernizing Land Information Systems in North America, December 1984.

8. STATUS OF DETAILED SOIL MAP DIGITIZING; S. Jordan; SCS, Cartography & GIS Division, Washington, D.C.; June 3, 1985; 14 pages; the status of soil map digitizing available from various agencies.

9. GEOGRAPHIC SOIL DATA BASE DEVELOPMENT; W. U. Reybold, G. W. TeSelle; SCS, Washington, D.C.; July, 1983; 10 pages; the desirability of and the planning involved in the development of a geographic soil data base by the NCSS.

10. SOIL RESOURCE DATA BASE-DEVELOPMENT; G. L. Decker; SCS, Cartography & GIS Division, Washington, D.C.; June, 1984; 14 pages; A seminar presented at the Northeast Cooperative Soil Survey Conference, Univ. of Mass., Amherst, MA., June 11-15, 1984.

11. CGIS DIVISION COMPUTER SYSTEMS INFORMATION AND HARDWARE CONFIGURATIONS AND SPECIFICATIONS; S. Jordan et al.; SCS, Cartography & GIS Division, Washington, D.C; November, 1985; 7 pages.

12. NATIONAL CELLULAR MAPPING PROGRAM - NATIONAL CARTOGRAPHIC CENTER WORKSHOP; D. Gaster, A. Molina; SCS, SNTC National Cartographic Center, Ft. Worth, TX; March 6, 1984; 26 pages; a seminar presented at the NCC workshop giving a brief description of the National Cellular Mapping Program and samples of maps from that program.

13. COMPUTER ANALYSIS OF SOIL AND LAND USE CONDITIONS IN THE POND CREEK WATERSHED - OKLAHOMA; SCS, Soil Survey Section, Stillwater, OK; October, 1983; 21 pages; a trial analysis documenting the results of a watershed study.

14. SOIL SURVEY MAP DIGITIZING AND GEOGRAPHIC INFORMATION SYSTEM PROGRAM; G. TeSelle; SCS, Cartography & GIS Division, Washington, D.C.; March 5, 1984; 4 pages; a briefing on the CGIS Division program for NCSS map digitizing and GIS development.

15. PROJECT ACTIVITIES - GIS USE & DEVELOPMENT AND SOIL SURVEY DIGITIZING DEVELOPMENT; E. Chapman; SCS, Cartography & GIS Division, Washington, D.C.; February 20, 1985; 9 pages; a summary status paper.

16. SOIL MAP DIGITIZING BY COMMERCIAL CONTRACTING; S. Jordan; SCS, Cartography & GIS Division, Washington, D.C.; January 1986; 17 pages; a history and description of the pilot soil map contract digitizing projects by CGIS through May 1985.

17. SUMMARY OF GEOGRAPHIC INFORMATION SYSTEMS - SCS STATE OFFICE ACTIVIITIES AND COOPERATIVE EFFORTS; E. Chapman; SCS, Cartography & GIS Division, Washington, D.C.; March, 1985; 8 pages; a brief summary of the status of GIS activities in each participating SCS State Office.

18. STATE GENERAL SOIL MAP GEOGRAPHIC (STATSGO) DATA BASE; W. Reybold; SCS, Washington, D.C.; November, 1984; 8 pages; SCS National Instructions giving the specifications and procedures for compiling state general soil maps for a digital geographic soil data base.

19. SOIL SURVEY POLICY ON MAP DIGITIZING; W. Reybold; SCS, Washington, D.C.; April, 1984; 4 pages; SCS National Soils Handbook amendment setting Agency policy for map digitizing.

20. RECOMPILING PUBLISHED SOIL SURVEY MAPS ON ACCURATE BASES FOR DIGITIZING; E. Sautter; SCS, Storrs, CT.; G. TeSelle, S. Jordan; SCS Cartography & GIS Division, Washington, D.C.; March, 1983; 10 pages; details the problems and procedures of map recompilation to bases sufficiently accurate for map digitizing.

21. REPORT OF SOIL MAP RECOMPILATION TEST PROJECT; E. Sautter; SCS, Storrs, CT.; July, 1983; 3 pages; a synopsis of the situations, concerns and problems encountered on a test project.

22. SCS COORDINATORS FOR CARTOGRAPHY, REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEMS; SCS, Cartography & GIS Division, Washington, D.C.; March, 1985; 3 pages; a listing of all State Office & National Office Coordinators for Cartography, Remote Sensing & GIS.

23. DIGITAL CARTOGRAPHY DATA STANDARDS ACTIVITIES; G. TeSelle; SCS, Cartography & GIS Division, Washington, D.C.; September, 1985; 17 pages; an overview of the FICCDC Standards Working Group activities for FY 85.

24. CGIS NEWSLETTER - Current edition; E. Chapman, R. Liston, G. TeSelle, G. Rohaley, O. Bockes; SCS, Cartography & GIS Division, Washington, D.C; produced quarterly; an overview of recent developments in the GIS, remote sensing and cartographic disciplines.

25. INTERACTIVE DIGITIZING, TAGGING & EDIT SOFTWARE SPECIFICATIONS; E. Chapman, R. Liston; SCS, Cartography & GIS Division, Washington, D.C.; December 1985; 14 pages; specifications primarily applying to software required for preparation of digital cartography soils data using point, line and line-segment (arc/node) digitizing methods.

26. DEVELOPMENT PLAN FOR PILOT TESTING & IMPLEMENTING GEOGRAPHIC INFORMATION SYSTEM (GIS) SOFTWARE ON FOCAS HARDWARE; R. Liston, E. Chapman; SCS, Cartography & GIS Division, Washington, D.C.; November 20, 1985; 9 pages; the development plan for pilot testing & implementation of GIS software on FOCAS hardware.

27. SCS SPATIAL DATA MANAGEMENT COMMITTEE REPORT: SCS, Washington, D.C.; December, 1981; 61 pages; Identification of SCS uses and requirements for a GIS system; Recommendations on methods for digitizing detailed soil surveys and future operating procedures for the Advanced Automated System (AMS).

28. THE USE OF SOILS INFORMATION IN FWS' MOSS GIS: A CASE STUDY IN LARIMER COUNTY, COLORADO; D. Anderson; FWS, Ft. Collins, CO.; G. TeSelle; SCS, Washington, D.C.; August, 1984; 6 pages; the objectives and processes involved in the Larimer, CO. case study.

29. DEVELOPING A DIGITAL SOIL SURVEY DATA BASE FOR CONNECTICUT - PROJECT PROPOSAL FY 86; E. Sautter; SCS, Storrs, CT; July, 1985; 14 pages; the proposal and documentation required to implement a cooperative project between state and federal agencies.

30. CONNECTICUT PROJECT OF AUTOMATING SOILS; E. Sautter; SCS, Storrs, CT; March, 1984; 2 pages; a briefing paper presented at the NCC Cartographic Workshop, Ft. Worth, TX.

31. SCS HELPS BUILD STATEWIDE GEOGRAPHIC INFORMATION SYSTEM IN CONNECTICUT; Nancy Garlitz; SCS, Washington, D.C.; July 1985; 1 page; article printed in the Soil and Water Conservation News, July, 1985.

32. STUDY PLAN - GEOGRAPHIC INFORMATION SYSTEMS PILOT TEST UTILIZING DATA GENERAL MINICOMPUTERS; E. Chapman; SCS, Cartography & GIS Division, Washington, D.C.; July 1984; 21 pages; a strategy for the implementation, testing and evaluation of MOSS/MAPS/COS GIS software within SCS.

33. STRATEGY FOR IMPLEMENTING GEOGRAPHIC INFORMATION SYSTEM TECHNOLOGY WITHIN THE SOIL CONSERVATION SERVICE; G. TeSelle, E. Chapman, R. Liston; SCS, Cartography & GIS Division, Washington, D.C.; January 1986; 4 pages; to be presented at the FS, GIS Workshop, Atlanta, GA., April, 1986.

34. GEOGRAPHIC INFORMATION SYSTEM (GIS) BRIEFING BROCHURE; E. Chapman, G. Rohaley, G. TeSelle; SCS, Cartography & GIS Division, Washington, D.C.; March, 1986; 22 pages; information and graphics depicting GIS capabilities.

35. USE OF SLOPE, ASPECT, AND ELEVATION MAPS DERIVED FROM DIGITAL ELEVATION MODEL DATA IN MAKING SOIL SURVEYS; A. A. Klingebiel, SCS, E.H. Horvath, Technicolor Government Services, D. G. Moore, USGS, W. U. Reybold, SCS; November 1985; 16 pages; a report on a cooperative project between USGS, SCS and BLM in evaluating digital elevation products for supporting order-three soil survey efforts.

36. SCS FOCAS BASED GIS PILOT TEST PLAN; R. Liston, G. TeSelle, E. Chapman; SCS, Cartography and GIS Division, Washington, D.C.; April 1986; 12 pages; plan for pilot testing selected public domain micro-based GIS software.

37. SCS, COMPUTERVISION SYSTEM, IMPORT AND EXPORT CAPABILITIES ON MAGNETIC TAPE; S. Jordan, R. Glenn; SCS, Cartography & GIS Division, Washington, D.C.; April 1986; 4 pages; this paper defines the available formats for exchanging digital geographic data.

ATTACHMENT C

Non-SCS Technical Papers pertaining to GEOGRAPHIC INFORMATION SYSTEMS (GIS)

1. THE CREATION OF A VERMONT STATE DATA BASE; G. Smith; School of Natural Resources, University of Vermont, Burlington, VT.; April 1983; 22 pages; strategy for creating a statewide data base using GIS technology.

2. EVALUATING NONPOINT POLLUTION USING REMOTELY SENSED DATA IN SOIL EROSION MODELS; R. Pelletier; NASA, National Space Technology Laboratory, MS.; July/August 1985; 4 pages; published in the Journal of Soil and Water Conservation.

3. COMPUTERIZED SOIL MAPPING IN MINNESOTA, 1965-1985; Minnesota State Planning Agency, PIC, LMIC, St. Paul, MN.; August, 1985; 26 pages; history of computerized soil mapping in Minnesota.

4. COMPUTERIZED SOIL MAPS BENEFIT CROP MANAGEMENT; R. Rust, P. Roberts; University of Minnesota, St. Paul, MN.; April, 1985; 5 pages; published in the magazine Farming with Pride, Vol. 5 - No. 4.

5. THE VIEW FROM ON HIGH - MICO-BASED PROCESSING OF SATELLITE IMAGERY; T. McMillan, Managing Editor; December, 1985; 4 pages; published in Computer Graphics World, December, 1985.

6. GEOGRAPHIC INFORMATION SYSTEMS FOR NATURAL RESOURCE MANAGEMENT; S. Walsh; Center for Applications of Remote Sensing, Oklahoma State University, Stillwater, OK.; March-April, 1985; 4 pages; published in the Journal of Soil and Water Conservation, March-April, 1985.

7. MONITORING SOIL SALINITY; J. D. Rhoades, D. L. Corwin; ARS, Soil Salinity Laboratory, Riverside, CA.; May-June, 1984; published in the Journal of Soil and Water Conservation, May-June, 1984.

8. APPLIED COMPUTER GRAPHICS IN A GEOGRAPHIC INFORMATION SYSTEM: PROBLEMS AND SUCCESSES; C.L. MacDonald, I. K. Crain; Canadian Department of the Environment, Canada Land Data Systems, Ottawa, Canada; October, 1985; 6 pages; published in IEEE CG&A, October, 1985.

9. USGS/CONNECTICUT GIS PROJECT; USGS, Reston, VA; Connecticut Department of Environmental Protection, Natural Resources Center, CT.; June, 1985; 19 pages; a project report presented at the U.S. Geological Survey/Connecticut Computer Demonstrations, Mystic, CT., June 3 - 7, 1985.

10. RHODE ISLAND GEOGRAPHIC INFORMATION SYSTEM NEWSLETTER; Rhode Island P. V. August; Department of Natural Resource Science, Environmental Data Center, University of Rhode Island, Kingston, RI.; January, 1986; 4 pages; Vol. 1, No. 1. and subsequent newsletters as they become available.

11. FEDERAL GEOGRAPHIC EXCHANGE FORMAT (Draft); Standards Working Group, Federal Interagency Coordinating Committee on Digital Cartography; May 1986; 67 pages; a specification designed to establish a standard format for the exchange of spatial data among federal agencies.

12. DIRECT APPLICATION OF THE SOI-5 SOIL INTERPRETATION RECORDS TO A GEOGRAPHIC INFORMATION SYSTEM; G. Smith, D. Sousa; School of Natural Resources, University of Vermont, Burlington, Vermont; April 1985; 8 pages; a description of the efforts by the School of Natural Resources to capture and incorporate the SOI-5 interpretation records in the schools ARC/INFO GIS.

Application Presentations

(abstracts and papers)

GEOGRAPHIC ANALYSIS OF ALASKA'S NATIONAL WILDLIFE REFUGES

Frank J. D'Erchia
Branch of Geographic Information Systems
Office of Information Resources Management
U. S. Fish and Wildlife Service
1011 East Tudor Road
Anchorage, Alaska 99513

ABSTRACT

This paper discusses the Map Overlay and Statistical System (MOSS) and its role in formulating management proposals for Alaska's National Wildlife Refuges. Region 7 of the U.S. Fish and Wildlife Service is responsible for providing a Comprehensive Conservation Plan for each of the 16 refuges located in Alaska by the end of 1987. The total area involved is greater than 77 million acres. Given this vast acreage and the time constraints imposed, concise evaluation and analysis of the data would be an almost impossible task without the aid of an automated geoprocessing software package.

The procedures followed include a preplanning process, where the directives and analysis priorities are determined for each refuge; data collection; data analysis and evaluation. A discussion of these procedures will be followed by a section on special projects. Specific applications and enhancements of MOSS will also examined.

Subsequent to the completion and analysis of a refuge data base, the MOSS software and refuge data base can be installed at the field office, where it will be available as a tool to aid in future management. The data analysis for about half the refuges is now complete, with the remainder in progress. The present status of the refuges, with regard to geoprocessing, will be summarized.

INTRODUCTION

When Congress passed the Alaska National Interest Lands Conservation Act (ANILCA) in 1980, one requirement was that Region 7 of the U.S. Fish and Wildlife Service (USFWS) prepare a Comprehensive Conservation Plan (CCP) for each of the 16 National Wildlife Refuges located in the state, with a deadline of December, 1987. Given these time constraints and more than 77 million acres of land involved, this would be a formidable task indeed without the use of an automated geoprocessing system.

Implementation of the Map Overlay and Statistical System (MOSS) for data analysis and product generation has been invaluable in providing timely and accurate results as well as detailed cartographic products for display and publication.

On most of the refuges those variables analyzed are similar; i.e., wildlife distribution, land ownership and hydrography. However, some refuges contain valuable mineral resources, and applications for development in these areas will require a more detailed analysis. A section of this paper will discuss some of the special projects encountered.

DISCUSSION

Procedures

Planning teams are responsible for the final CCP documentation for each refuge. These teams prepare planning directives to set forth the steps, products, objectives, personnel, costs, responsibilities and schedules required to complete the plan. Once the preplanning is complete, the refuge staff collects the data related to cultural and natural resources, including both current uses and future demands. The next step is the analysis of these data. While one of the first CCPs was completed without the use of an automated geoprocessing system, the remaining rely heavily upon MOSS and other software packages in order to expedite the process, provide reliable output products and build a data base which each refuge can utilize in the future.

The Region 7 Branch of Geographic Information Systems (GIS) has developed and refined a series of steps for initiating and establishing a geographic data base. When a project is first formulated a preliminary analysis is conducted wherein objectives, needs, goals, output products and costs are discussed. In some cases, when the project is designed to meet an immediate, short-term goal, this may be all that is necessary. However, if long-term use of the proposed data base is foreseen, a more formal user needs analysis is conducted wherein data entry costs are estimated, users are defined and detailed information for map scale, data sources, accuracy and reliability are discussed and documented. This is done primarily in order to avoid interruption of the process due to a missing data element, but in addition, this discussion may alert the user to a less circuitous way of obtaining the desired results. Once the data is collected and captured via digitization or other data entry means, the next step is to construct a data base. Concurrent to this a data dictionary is initiated. The MOSS map header information alone does not constitute a data dictionary; first, a standard map-naming convention is essential. With diligent use of the ten allowable characters for map names, one can define the project, theme, data type and projection or other items of importance so that the contents of a data base can be ascertained by simply browsing the list of map names. For example, the map name YKDHYD23 was used for a map in Project Yukon Delta NWR (YKD), containing hydrology data (HYD) of line type (2) and projected in UTM (zone 3). Other naming conventions may sometimes be more suitable, but it is important that one be clearly defined and maintained. In addition, information on subject or multiple attribute coding should be documented, which could also contain other pertinent information such as the names of those responsible for data collection and coding.

Data Analysis

Data to be analyzed are gathered by various methods. During the field season the staff gathers information on wildlife use areas, which is entered as polygons and/or animal sightings, which are recorded as point locations. Other data types include stream segments and refuge boundaries, which are entered as line data. In addition, Landsat imagery is utilized to provide land cover, elevation, slope and aspect data in a cell format. This data is imported into MOSS (MAPS) and processed with rasterized vector data, such as wildlife use areas, to model vegetation and terrain habitat.

A case in point was a lynx habitat model for Koyukuk NWR. Once the land cover image was imported, the values of interest were extracted, including three categories of food types (alluvial and lowland tall scrub, moist herbaceous and dry herbaceous) and three values of cover types (open needleleaf forest, mixed needleleaf-deciduous forest and needleleaf woodland). The next step was to use the proximity command to determine how many cells of each food type were within 200 meters of the three cover types. The output products included a plot for visual location of these areas on the refuge and a table of area calculations listing the amount of acreage existing in each category.

The first priority is to provide the planners with analysis requirements to help meet the mandated deadlines. Once this is accomplished for each individual refuge, the next step is to install the MOSS software and the refuge data base at the refuge field office. This is somewhat dependent upon budgetary constraints and management objectives, but a few of the refuges are currently utilizing MOSS and several others have requested the capability and will be operational within a year. The refuge staff will then have an additional tool at their disposal to aid in future refuge management.

Output Products

Output products primarily consist of paper or mylar plots and summary tables. The use of these products ranges from informal meetings conducted in villages located within refuge boundaries, where the unique situation of subsistence hunting must be considered in wildlife management decisions, to inclusion in reports that will be presented to Congress.

To expand the display capabilities a program was designed that will write the plot file to an intermediate file. A second program allows the user to display the plot file on a number of devices. The availability of a color terminal along with a color hard copy device has proven particularly useful for previewing the plot as it will look in its final form and to locate errors prior to plotting. In addition, color copies for distribution at meetings, black-and-white or color copies for publication, or transparency film copies suitable for overhead projection can be readily prepared. Summary tables generally contain area calculations which are taken directly from MOSS and are modified using a text editor before a hard copy is produced.

Special Projects

The development required to recover valuable resources on a refuge and the associated impact on wildlife habitat requires a more detailed and intensive analysis. One such case is the 1002 area of Arctic NWR (from section 1002 of ANILCA). It has been estimated that the oil reserve here will exceed that of the vast Prudhoe Bay discoveries, located less than 100 miles east of the refuge boundary. This area includes a large portion of the migration route of the Porcupine caribou herd, with roughly 100,000 animals, one of the largest herds in Alaska. The caribou favor particular portions of the refuge for calving and coastal areas to escape insect infestation during the summer months. Arctic NWR also provides habitat for muskox, Dall sheep, wolves, polar and grizzly bear, as well as 140 bird species. Proposed development data was released by the oil companies to USFWS for analysis. At the time of publication of this paper, that data remained confidential. However, a hypothetical scenario was generated for use by biologists attending The Caribou Impact Analysis Workshop, Arctic NWR, 19-20 November 1985, for their input on the potential effects the development will have on the caribou habitat. The hypothetical development scenario (see Figure 1) includes haul roads, pipeline, drill pads with connecting roads, large and small processing facilities, ports and airfields. In our analysis the actual proposed development data was available for a multitude of processes, including buffer and overlay, to determine areas of conflict. Several unique projects resulted from this study that subsequently utilized the geoprocessing capabilities of MOSS. The following studies are two examples of the analysis process.

The first study involved the Porcupine caribou herd calving grounds. Polygonal data had been collected over a span of thirteen years (from 1972 to 1985) for areas of major concentrations of caribou calving. When these overlapping polygons were digitized, a number of small polygons were created and each was assigned a unique sequential number. A code sheet was constructed listing the years that calving was observed within each polygon, with the total number of years being the significant observation. As it turned out, the range had from one to nine years of repeated use. A simple graphic display of the leasing scenario and the calving grounds plotted together indicated imminent conflict in an area preferred by caribou for calving (see Figure 2). This observation led to the proposal for an alternative leasing scenario which eliminated development in this critical area (see Figure 3). These types of displays, along with tables containing acreages of affected habitat, will be included in the proposals made to Congress, where the ultimate fate of the Arctic NWR will be decided.

The second project, also critical to the Arctic NWR study, dealt with "home-range" calculations for caribou, wolves, eagles, muskox and grizzly bear. Data was collected for this study by radio-tracking of collared animals. The point locations for each collared animal were observed several times each year, and these points were digitized and reformatted into a MOSS import file. Another file was generated containing the location number, collar number, date and time of observation. Using a sort/merge routine, these files were combined into a master file containing all information for all years by species. A program was written which extracted the necessary information from this master file to create both a point export file and a line export file, with vectors connecting the points in a time-ordered sequence. The attribute string for the points was set up so that an animal could be selected by collar number and year. The vector map has a similar attribute string, in addition to calculations for azimuth from one point to the next, distance between points and time elapsed between sightings. These files were added to MOSS as master point and line maps for each species. From these maps selections were made based on collar number and year and plotted at a scale of 1:250000. These plots were overlaid on a standard quadrangle on a light table, where the boundaries for home range could be traced based on terrain and the biologists' knowledge of animal behavior. The polygons were subsequently digitized and added to MOSS. Area calculations were made and the effects of the proposed development were analyzed. Further studies will compare these results to existing harmonic models to evaluate their usefulness in calculating home range. Other research will analyze the interaction by intra- and inter-species in relation to habitat use.

SUMMARY

The advantages of having geoprocessing capabilities are clear. Whether an individual user will continue to reap these benefits, however, is not. It has taken several years to formulate the systematized method implemented by USFWS Region 7, and it is still evolving. As previously stated, it is imperative to maintain documentation, detailed data dictionaries and a systematic approach throughout the duration of the project. The flow chart in Figure 4 represents the process currently employed by the Branch of GIS.

Of the sixteen NWRs located in Alaska, CCPs have been completed for five (Alaska Peninsula, Becharof, Izembek, Tetlin and Togiak). A data base has been constructed for twelve (Alaska Peninsula, Arctic, Becharof, Izembek, Kanuti, Kodiak, Koyukuk, Nowitna, Tetlin, Togiak, Yukon Flats and Yukon Delta) and initiated for two (Innoko and Selawik). Of the remaining two, Kenai was not required to produce a CCP and Alaska Maritime is basically a state-wide data base. However, both of these refuges have initiated special projects that will require geoprocessing. GIS support for Alaska's NWRs is handled by the Branch of GIS, Office of Information Resources Management, located in the Regional Office in Anchorage. Several MOSS training courses have been held at the regional office for refuge staff members prior to installation of MOSS at the field stations. MOSS is presently in use at several refuges: two groups at Arctic NWR, Research and Refuge Management, are using MOSS and are working with data base constructed at the regional office; Yukon Delta NWR is currently being set up with MOSS; and Innoko NWR and Kodiak NWR have requested installation of MOSS. In addition, interest has been expressed by several other refuges, which are currently taking the initial steps necessary to acquire MOSS at their field offices.

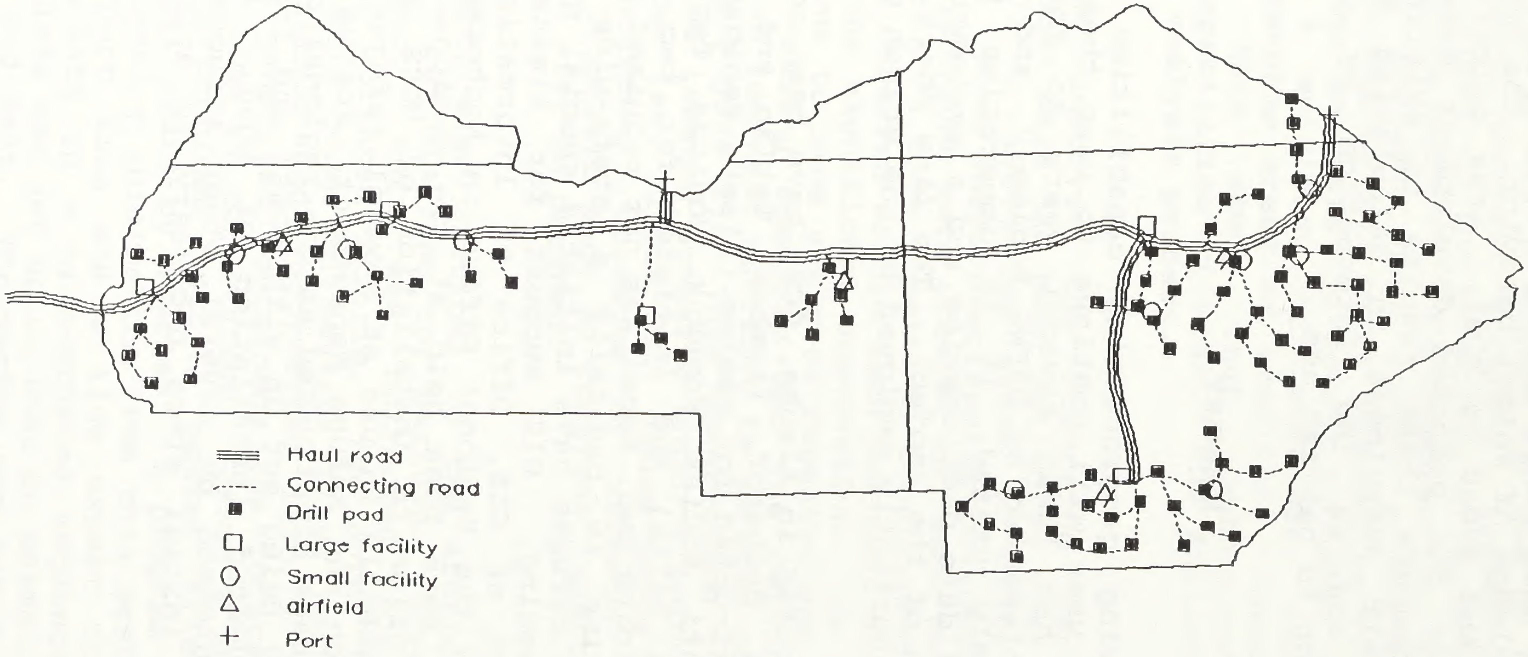


Figure 1. Map of the 1002 area and hypothetical development scenario.

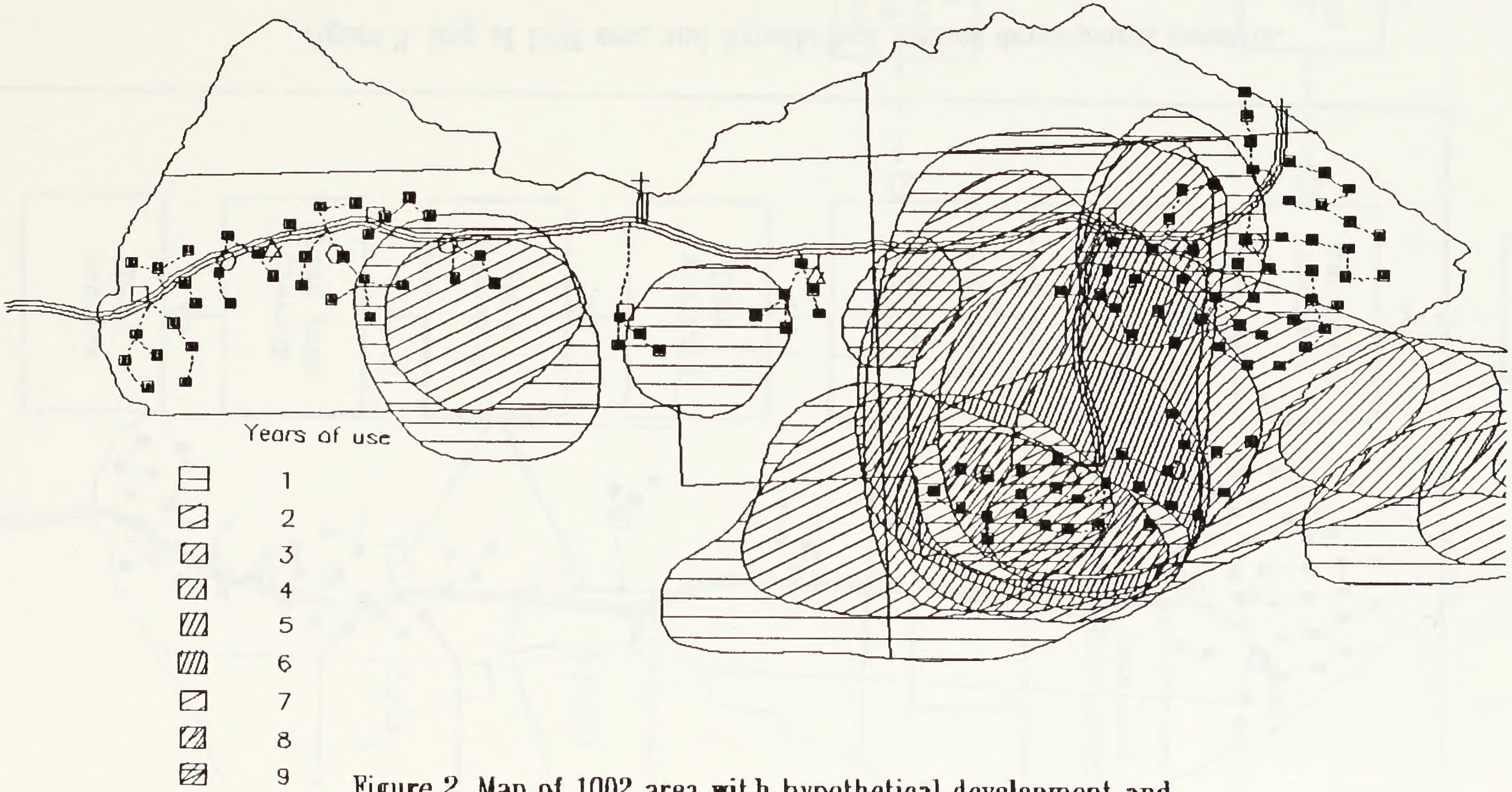


Figure 2. Map of 1002 area with hypothetical development and caribou calving grounds.

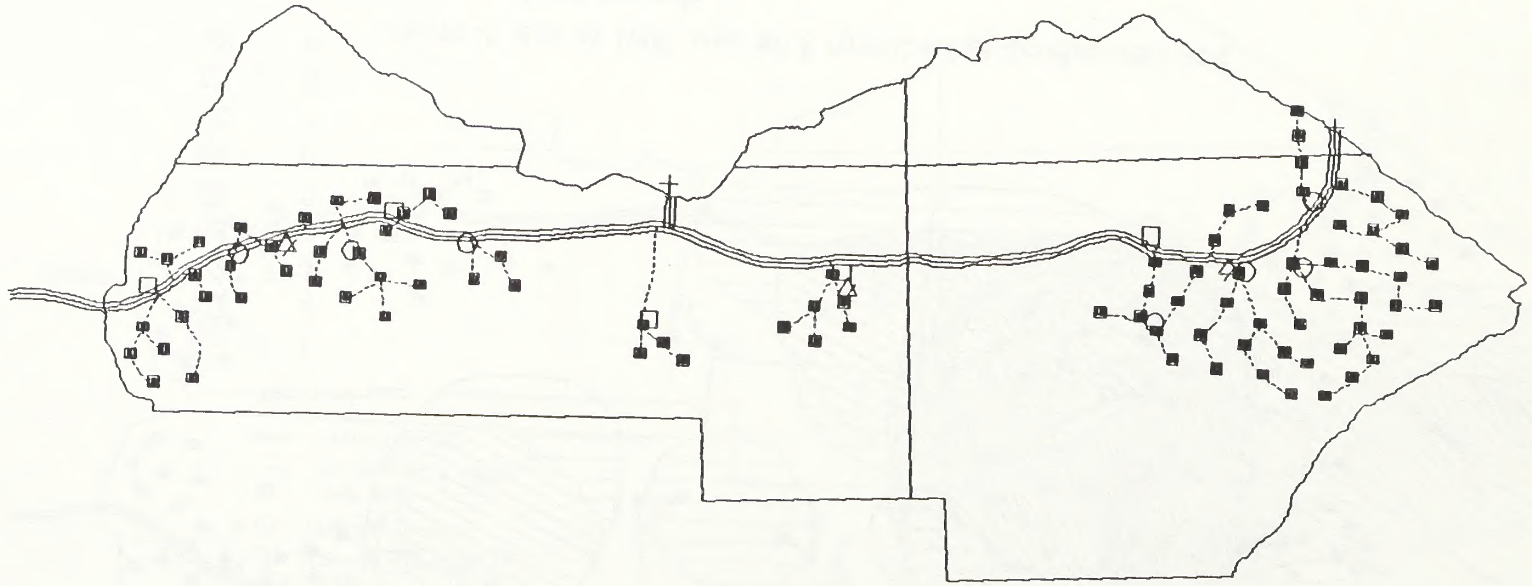


Figure 3. Map of 1002 area and hypothetical limited development scenario.

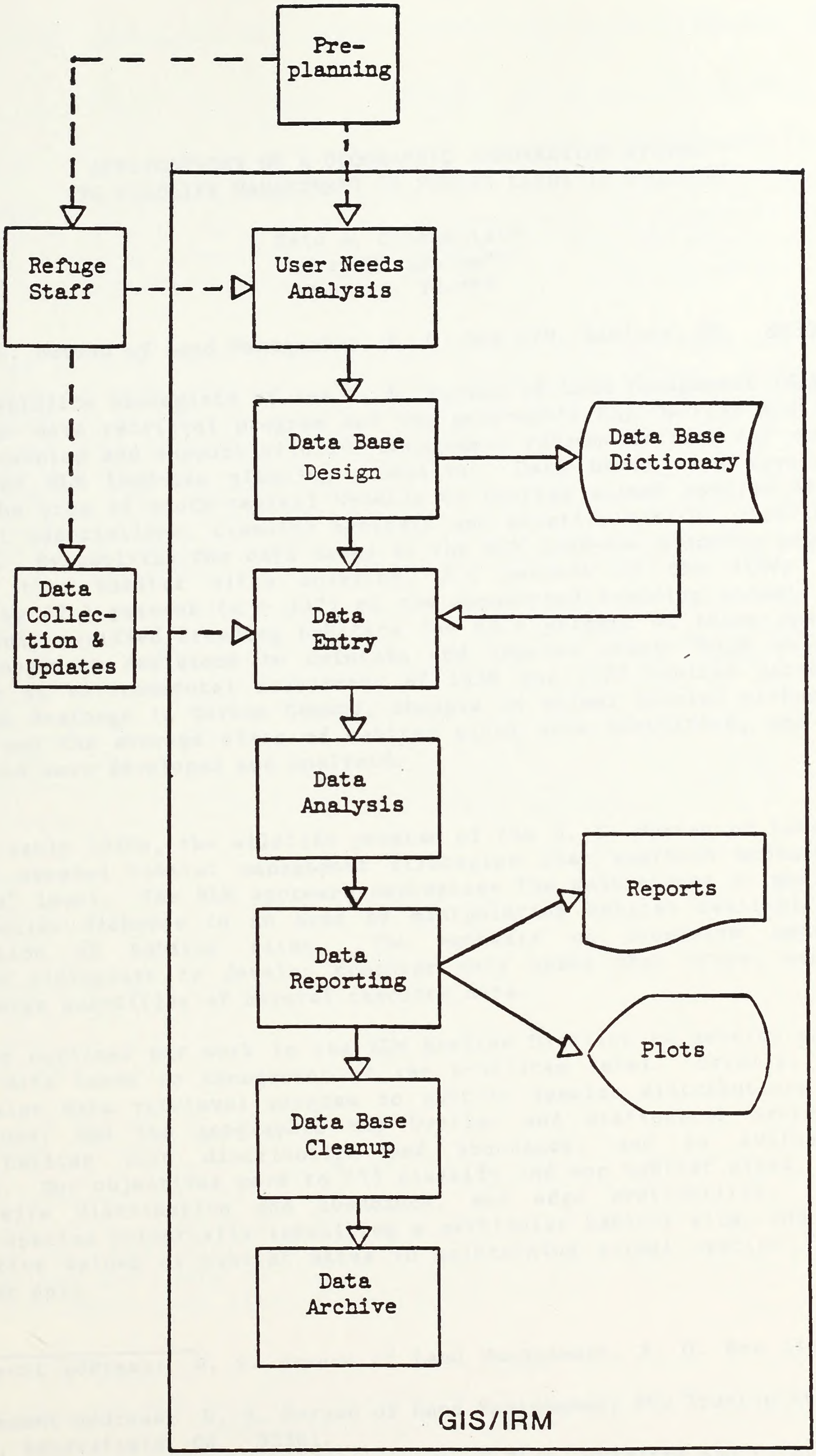


Figure 4. Data Base Management Process

APPLICATIONS OF A GEOGRAPHIC INFORMATION SYSTEM TO WILDLIFE MANAGEMENT ON PUBLIC LANDS IN WYOMING

Eric A. Greenquist*
Larry R. Saslaw**
Chris A. Yde***

U. S. Bureau of Land Management, P. O. Box 670, Rawlins, WY 82301.

ABSTRACT--Wildlife biologists of the U. S. Bureau of Land Management (BLM) used the INFO tabular data retrieval program and the geographic Map Overlay and Statistical System to develop and support wildlife management recommendations for environmental analyses and BLM land-use planning processes. Data bases were developed for a 1,348,460 ha area of south-central Wyoming to portray animal species distributions and habitat associations, classify habitats and quantify habitat distributions and abundances. By applying the data bases to the BLM land-use planning process it was determined that habitat sites covering, 7.4 percent of the study area, were inhabited by 67.1 percent (n = 237) of the documented breeding animal species and were the only verified breeding habitats for 43.9 percent of these species. This led to management decisions to maintain and improve these "high value" habitat sites. In an environmental assessment of 1938 and 1982 habitat patterns in the Muddy Creek drainage in Carbon County, changes in animal species richness, habitat diversity and the average sizes of habitat sites were quantified, and reclamation alternatives were developed and analyzed.

Since the early 1970s, the wildlife program of the U. S. Bureau of Land Management (BLM) has adopted habitat management strategies that approach management at the "ecosystem" level. The BLM approach emphasizes the maintenance or modification of animal species richness in an area by manipulating habitat availability and the juxtaposition of habitat sites. The emphasis on ecosystem management has encouraged biologists to develop computer data bases that store, manipulate and display large quantities of natural resource data.

This paper outlines our work in the BLM Rawlins District to develop and apply two computer data bases to management at the ecosystem level. Briefly, we used the INFO tabular data retrieval program to portray species distributions and habitat associations, and the geographic Map Overlay and Statistical System (MOSS) to analyze habitat site distribution and abundance, and to evaluate land-use conflicts. Our objectives were to (1) classify and map habitat sites, (2) quantify habitat site distribution and abundance, and edge availability, (3) list the wildlife species potentially inhabiting a particular habitat site, and (4) quantify the relative values of habitat sites in maintaining animal species richness in a management unit.

---

*Present address: U. S. Bureau of Land Management, P. O. Box 518, Cody, WY 82414.

**Present address: U. S. Bureau of Land Management, 800 Truxtun Avenue, Room 311, Bakersfield, CA 93301.

***Present address: Montana Department of Fish, Wildlife and Parks, P. O. Box 67, Kalispell, MT 59903.

METHODS

Development of the INFO Data Base

We created INFO and MOSS data bases for the 1,348,460 ha BLM Divide Planning Unit in Carbon and Sweetwater counties, Wyoming. INFO was developed by Henco Software, Inc., Waltham, MA for use with the Honeywell DPS6 computer. A report of the INFO data base is shown in Table 1.; data can be sorted by any combination of the categories.

Data used in the INFO data base were representative of that normally collected by State and Federal resource management agencies. BLM and Wyoming Game and Fish Department (WGFD) biologists gathered habitat occurrence data on nongame wildlife species according to standardized, statewide methods (Wyoming Game and Fish Dep. 1981). Habitat occurrence data on game species were obtained from seasonal surveys and casual observations. Field data were supplemented with information on statewide mammal and bird distributions and habitat associations (Findholt et al. 1981, Oakleaf et al. 1982), and a literature review. We compiled information on 445 vertebrate species known or suspected to inhabit the planning unit.

We performed line intercepts (Hays et al. 1981:40-43) on 137 habitat sites that we believed encompassed all major vegetative communities in the planning unit. At each site, we recorded estimated vegetation height, soil type, estimated area of the habitat site, adjacent habitat sites, elevation, aspect, slope, associations with geographic features and all observed wildlife species. Habitat sites were subjectively grouped into 24 "standard habitat sites" (U.S. Dep. Inter. 1981) according to similarities in site locations, landform associations and plant and animal species occurrences, and our management priorities.

Development of the MOSS Data Base

MOSS themes were created through the Automated Digitizing System (ADS). This system was developed by the U. S. Fish and Wildlife Service and the BLM for use with the Data General M600 computer to "capture" and edit spatial data. Data were manually digitized from 1:24000 map overlays using a CalComp 9000 digitizing table and a Tektronix 4054 graphic terminal. The graphic terminal was used to refine and transfer data to the MOSS, perform MOSS functions, display data and create hard copy plots with a Data General 6053 dasher terminal and a CalComp 1073 plotter.

To create the standard habitat sites theme, soil scientists of the BLM and the U.S. Soil Conservation Service examined black and white orthographic photographs (1:24,000) of the planning unit and delineated polygons (104.8 ± 482.8 ha) that appeared to form uniform vegetation types. BLM range scientists inspected polygons on the ground and estimated the relative composition of dominant plant species by weight (U.S. Dep. Agric. 1976: Section 305). Polygons were stratified according to precipitation zone, range site, ecological condition, and local variations in the structure of vegetation. Polygons containing multiple range sites were placed into multiple strata.

We then developed a conversion program that assigned a standard habitat site code(s) to each polygon given range site(s) and stratum (strata) data. The finished conversion was the MOSS standard habitat sites theme.

Table 1. An INFO report of eight species, showing data base format and content.

a	b						c	d	e	f	g		h				i	j																							
SPECIES	17	18	19	24	25	26	SHF	AB	SU	LS	RE	FE	I	C	S	V	REF	WL	SI	GS	WW	AR	CR	RL	TS	BL	UM	SG	SS	SM	SR	GW	BS	MS	JW	QA	AC	LP	PD	HC	ES
BROOK TROUT[k]	B	B	B		B	B			R	G	W	W	A	A			8	KB																							
GR BASIN SPADEFT TOAD[l]	B	B	B	B	B		A33	3	R	N	W	UG	X				6	KB	KB	KB	KB	KB	KB							KB	KB	KB	KB								
BULLSNAKE[m]	B	B	B			B		3	R	N	U	G		X			6			KB								KB		KB	KB	KB	KB	KB	KB						
NORTHERN POCKET GOPHER[n]	H	B	B	B	H	B		3	B	N	U	UG				X	57		SB			SB					SB	SB		KB	SB			SB		SB	SB		SB	SB	
PRONGHORN[o]	B	B	B	B	B	B		3	B	G	G	G				X	3	FH	KB	KB	FH	FH						KB	KB	KB	KB	KB	KB								
PINTAIL[p]	B	B	B	B	B	B		4	R	G	G	GW				X	3	KP	SB	KB	KB	KB	KB								KP	FH				FH	FH				
ROUGH-LEGGED HAWK[q]	O	O	O	O	O	O		3	W	N		GA		X			3											OH	OH	OH	OH	OH			OH						
SPOTTED SANDPIPER[r]	B	S	B	S	B	B		3	S	N	WE	G	X				23	SP			SB	SB	SB													SB	FH				

---

[a] Common name.

[b] Breeding status for latilongs 17-19 and 24-26 (for latilong definition see Wyoming Game and Fish Dep. 1981b, 1982) indicating whether the species is (B) known to breed, (S) suspected to breed, has been (O) observed, or (H) occurred historically in each latilong.

[c] Species use of special habitat features (see U. S. Dept. Inter. 1982: Section 6602 for the list of special habitat feature codes).

[d] Statewide abundance: 1 = rare, 2 = uncommon, 3 = common, 4 = abundant, 5 = peripheral, 6 = undetermined.

[e] Statewide seasonal use: A = accidental, M = migrant (Fall and Spring only), R = yearlong resident, S = summer resident, W = winter resident.

[f] Legal status: E = endangered, F = high Federal interest, G = game, H = historical occurrence in state, N = nongame, T = threatened.

[g] Reproductive and feeding life form(s) (Thomas et al. 1979e:27-39): A = air, B = bush, C = any canopy, D = all above ground, E = emergent vegetation, G = on ground, H = hole in tree, L = cliff ledge, M = man-made structure, S = shoreline, T = tree, U = under ground, W = on or in water.

[h] Food source: I = invertebrate, C = carnivorous, S = seed, V = vegetation, and whether the food is (A) aquatic or (X) terrestrial.

[i] Information source codes.

[j] Standard habitat sites and whether the species is (KP) known to primarily breed, (KB) known to breed, (SP) suspected to primarily breed or (SB) suspected to breed in the habitat site, (FH) frequents the habitat site but breeds elsewhere, or (OH) has been observed in the habitat site. The standard habitat sites are (WL) wetland, (SI) subirrigated grassland, (GS) greasewood/sagebrush riparian shrubland, (WW) willow/waterbirch riparian shrubland, (AR) aspen riparian woodland, (CR) cottonwood riparian woodland, (RL) rockland, (TS) true sand dune, (BL) badland, (UM) upland meadow, (SG) short grassland, (SS) saltbush steppe, (SM) sagebrush/mixed grass steppe, (SR) sagebrush/rabbitbrush steppe, (GW) greasewood steppe, (BS) bitterbrush steppe, (MS) mountain shrubland, (JW) Utah juniper (*Juniperus osteosperma*) woodland, (QA) quaking aspen (*Populus tremuloides*) woodland, (AC) aspen/conifer woodland, (LP) lodgepole pine (*Pinus contorta*) forest, (PD) ponderosa pine (*Pinus ponderosa*) or Douglas-fir (*Pseudotsuga menziesii*) forest, (HC) highland conifer forest, and (ES) early successional conifer forest.

[k] *Salvelinus fontinalis*.

[l] *Scaphiopus intermontanus*.

[m] *Pituophis melanoleucas*.

[n] *Thomomys talpoides*.

[o] *Antilocapra americana*.

[p] *Anas acuta*.

[q] *Buteo lagopus*.

[r] *Actitis macularia*.

MANAGEMENT APPLICATIONS

We developed the INFO and MOSS data bases to better incorporate wildlife information and management concerns into environmental analyses and BLM land-use planning processes. Here, we provide examples of these applications, demonstrating the systems' capabilities we find most useful.

Land-use Planning

The data bases permitted us to determine the area of a standard habitat site in a management unit and tabulate species occurrence data. This enabled us to subjectively estimate the relative importance of a standard habitat site to the animal species richness of the unit.

We used this procedure to develop and support habitat management recommendations for the Divide Management Framework Plan (MFP): a principal planning document for the Divide Planning Unit. Ten standard habitat sites (coded in Table 1 as WL, SI, WW, AR, CR, MS, JW, QA, AC and PP), covering 7.4 percent of the planning unit, were inhabited by 67.1 percent (n = 237) of the documented breeding species and were the only verified breeding habitats for 43.9 percent of these species. These standard habitat sites also were inhabited by 76.9 percent (n = 173) of the federally listed threatened or endangered species, species of high federal interest, or statewide rare or uncommon species, known or suspected to occur in the planning unit. This documentation supported the final MFP decisions that restricted the types and amount of surface disturbances that could occur in these "high value" habitats and placed priority on their protection and improvement.

Environmental Analysis

We examined a portion of the Muddy Creek drainage in Carbon County to evaluate changes in habitat diversity and the occurrences of breeding species. Habitat patterns (Fig. 1A & B) were traced from high altitude aerial photographs taken in 1938 (1:7327 black and white) and 1982 (1:5985 color). Patterns were transferred by hand to black and white orthographic photographs (1:24000) to correct distortion and standardize the scale for digitizing. Standard habitat sites were verified

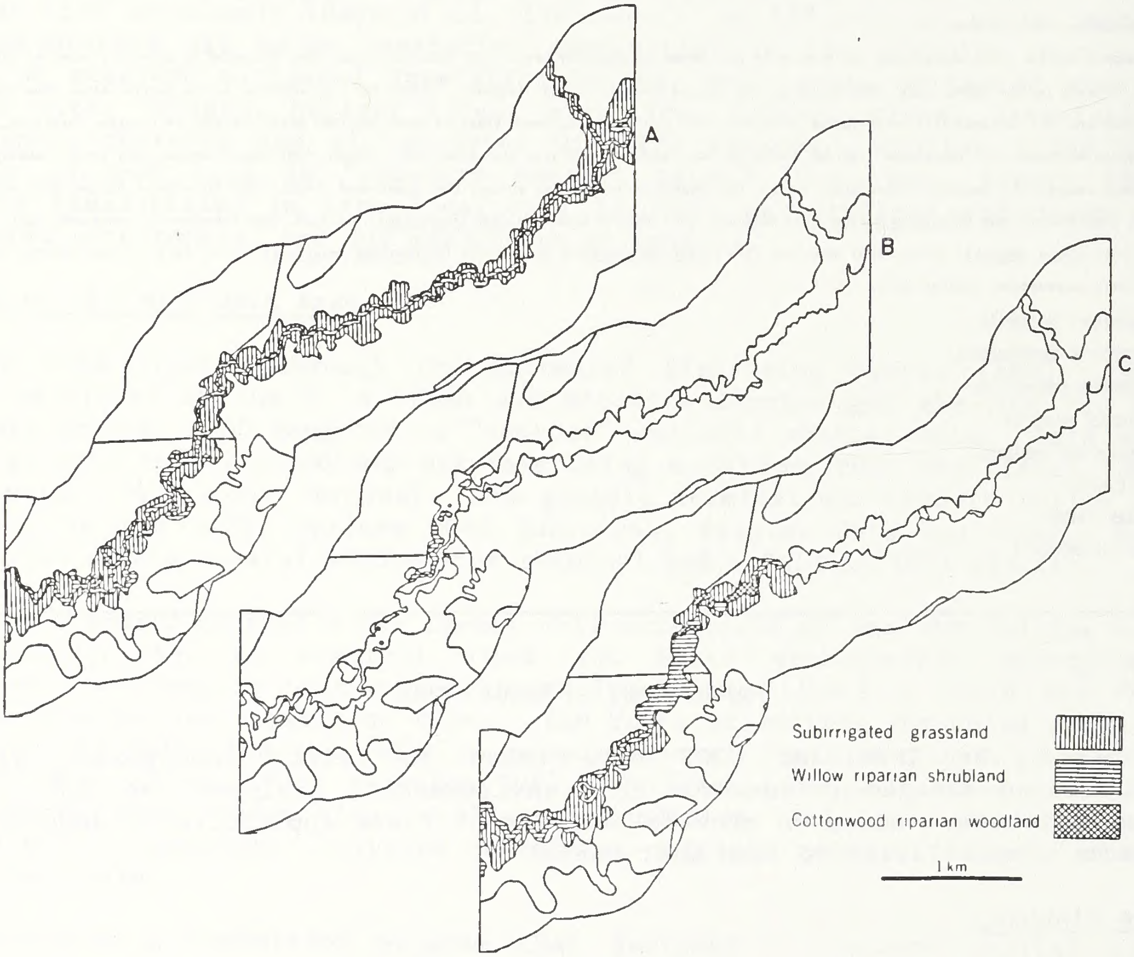


Fig. 1. The pattern of standard habitat sites for a portion of the Muddy Creek drainage, Carbon County, WY as it existed in (A) 1938, (B) 1982 and (C) as we believed it would exist after reclamation. Stream flow was from right to left. Only the high value standard habitat sites were shaded.

with stereoscopic inspection of 1938 black and white aerial photographs (1:30440), personal contact with the 1938 area resident, and 1982-1984 field inspections. BLM personnel began field evaluations of Muddy Creek in 1982 to determine the reclamation potential. We developed a "reclaimed" habitat pattern (Fig. 1C) to predict changes in habitat diversity and breeding species occurrences, by subjectively modifying the 1982 pattern based on field data and the reclamation plan (U.S. Dep. Inter. in preparation).

We plotted 0.5 km buffer areas around the habitat patterns and overlaid these areas with the standard habitat site theme. The MOSS was used to calculate habitat site polygon sizes and edge lengths.

Using INFO to retrieve a list of species by standard habitat site occurrences, 85 breeding species potentially inhabited the study area in 1938 compared to 79 species in 1982. By adding the structural components of cottonwood riparian woodland habitats, the proposed reclamation could bring the community to 109 breeding species. However, this tabulation ignores habitat parameters, such as the size of a habitat (Galli et al. 1976:356), that affect species numbers.

The average sizes of the available "high value" habitat sites in the Muddy Creek study area have decreased since 1938 and would increase with reclamation (Table 2). This supported the decrease and increase in numbers of breeding species suggested by the INFO tabulation. It also suggested that the species numbers stated above were too high since it was unlikely that all of the habitat components necessary to support these numbers were present in each habitat pattern. This was especially true for the 1982 estimate ; 18 of the 79 species tabulated for 1982 were only known to breed in willow riparian woodlands. The maximum polygon size of this standard habitat site in 1982 was only 2.1 ha; well below the probable optimal size (Galli et al. 1976:359).

Species numbers also tend to increase with increases in habitat edge and the contrast in vegetation structure across edges (Thomas et al. 1979b:52). We used the MOSS to measure polygon areas and perimeters, and expressed the availability of edge as diversity indices (Thomas et al. 1979b:54-58) (Table 2). Habitat diversity decreased from 1938 and was expected to remain stable with reclamation. In addition, the structural contrast across edges was predicted to improve with the increased "high value" standard habitat sites. This also supported the decrease and increase in numbers of breeding species suggested by the INFO tabulation.

Table 2. A comparison of changes in habitat diversity and the availability of high value habitats for that portion of the Muddy Creek drainage shown in Fig. 1. The analyses were based on the habitat pattern as it existed in 1938, 1982, and as we believed it would exist after reclamation. The number of polygons of each standard habitat site are shown in parentheses.

	1938	1982	Reclaimed
Availability of high value habitats (ha)			
subirrigated grassland	90.08 (24)	0	33.10 (14)
willow riparian shrubland	27.44 (8)	2.67 (4)	20.60 (6)
cottonwood riparian woodland	0	0	2.99 (3)
Diversity index	6.76	5.47	5.51

DISCUSSION

INFO and MOSS were chosen over other systems because they were easy to use and data bases could be developed with a reasonable effort, and because they were suitable for a variety of management applications. We also could use our own inventory data, making the data bases area-specific, and our information could more easily be integrated with other natural resource data bases, improving the utility of wildlife data in multiple-use management. Application of the data bases was qualified by 2 assumptions: (1) the wildlife standard habitat sites classification was defined and mapped in sufficient detail for sound management, and (2) the wildlife species occurrence information was accurate.

Although the standard habitat sites classification was subjective, it was sufficiently detailed for most BLM management situations. We are not however, satisfied with the MOSS standard habitat sites theme as it currently exists.

We examined 622 habitat sites on the ground in 3 areas of the planning unit; only 84.7 percent of the sites were correctly classified. Some of the standard habitat sites covered only small portions of polygons and were not recorded during the range inventory. Other standard habitat sites were distinguished more by structural variations than by differences in plant species compositions, and structural parameters were not recorded during the range inventory. Better accuracy would have been achieved by mapping habitat sites during the range inventory.

Although the INFO data base contains the best information readily available, errors undoubtedly exist. We have accounted for this by recording the source and quality of each species account so that future data collection can be directed to fill gaps in the data, and confirmed and postulated data can be separated.

BLM wildlife inventories produce various quality levels of information depending on funding, time, personnel, identified issues, and resource value constraints. The value of the systems we describe is that data base development can be done gradually and does not require a complete field inventory. Information from the literature and from existing computer data bases (e.g.; Patterson & Anderson 1983) can be incorporated into a site-specific data base. Although deficiencies in our data bases exist, they are due to inaccurate or insufficiently detailed data and do not reflect deficiencies with the INFO system or the MOSS.

Acknowledgments. Our work was supported entirely by the BLM. We thank A. William Alldredge, Brad Nelson, Craig Patterson and Donald Schrupp for their criticisms of the manuscript, and Robert Green, Gregory Hand and Charles Niemeier for writing the conversion program. We give special thanks to Larry Neasloney and Esther Simons for their help with the MOSS.

LITERATURE CITED

Findholt, S., B. Oakleaf & B. Long. 1981. Working draft of Wyoming mammal atlas. Wyoming Game and Fish Dep., Cheyenne. 27 pp.

Galli, A. E., C. F. Leck & R. T. T. Forman. 1976. Avian distribution patterns in forest islands of different sizes in central New Jersey. Auk 93:356-364.

Hays, R. L., C. Summers & W. Seitz. 1981. Estimating wildlife habitat variables. U. S. Dep. Inter., Fish and Wildl. Serv., FWS/OBS-81/47. 111 pp.

Oakleaf, B., H. Downing, B. Raynes, M. Raynes & O. K. Scott. 1982. Wyoming avian atlas. Wyoming Game and Fish Dep. and Bighorn Audubon Soc., Cheyenne. 87 pp.

Patterson, C. T. & S. H. Anderson. 1983. Progress report of a computerized vertebrate data base for Wyoming. 2 pp. National Workshop on Computer Uses in Fish and Wildlife Programs: a State of the Art Review, December 5 - 7. Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Thomas, J. W., R. J. Miller, C. Maser, R. G. Anderson & B. E. Carter. 1979a. Plant communities and successional stages. Pages 22-39 in J. W. Thomas, ed. Wildlife Habitats in Managed Forests: the Blue Mountains of Oregon and Washington. U. S. Dep. Agric., For. Serv., Agric. Handbook 553. 512 pp.

__________________, C. Maser and J. E. Rodiek. 1979b. Edges. Pages 48-59 in J. W. Thomas, ed. Wildlife Habitats in Managed Forests: the Blue Mountains of Oregon and Washington. U. S. Dep. Agric., For. Serv., Agric. Handbook 553. 512 pp.

U. S. Department of Agriculture. 1976. National Range Handbook - 1, July 13. U. S. Dep. Agric., Soil Conserv. Serv.

U. S. Department of the Interior. 1981. Standard habitat site classification: Divide Planning Unit. U. S. Dep. Inter., Bur. of Land Manage., Rawlins Dist. 32 pp. (Typescript.)

__________________. 1982. BLM Manual, March 26. U. S. Dep. Inter., Bur. of Land Manage., Washington, D. C.

__________________. In preparation. Draft Muddy Creek watershed plan. U. S. Dep. Inter., Bur. of Land Manage., Rawlins Dist. 104 pp. (Typescript.)

Wyoming Game and Fish Department. 1981. Summary of Nongame Census Technique Workshop, March 24. Wyoming Game and Fish Dep., Cheyenne. 24 pp. (Typescript.)

USE OF GEOGRAPHIC INFORMATION SYSTEMS (GIS) TO ANALYZE IMPACTS OF CO_2 GAS DEVELOPMENT ON ELK CALVING AREAS

Erik B. Brekke
Wildlife Biologist
Bureau of Land Management
Canon City District
Royal Gorge Resource Area
P.O. Box 1470
Canon City, Colorado 81212

ABSTRACT

Between 1980 and 1985, the Bureau of Land Management, in cooperation with ARCO Oil and Gas Company conducted spring elk surveys near La Veta, Colorado. ARCO was in the process of developing a large Carbon Dioxide (CO_2) gas field that would eventually be used for enhanced oil recovery in west Texas. In order to determine potential impacts to the elk herd, past research was reviewed, and traditional research techniques including aerial and ground observations were employed. A Geographic Information System (GIS), which captures, stores and analyzes geographic or spatial information, was used for data analysis. The GIS used in this study was the Map Overlay and Statistical System (MOSS). In addition to analysis of land ownership, habitat types, water sources, roads, pipelines and drillsites, the use of Digital Elevation Models (DEM) allowed analysis of elevation, slopes and aspects in the study area. A viewshed determination was also possible using DEM's. When intersected with elk sightings before and after drilling activity, statistical analysis indicated that elk shifted preferred habitats and distribution in order to avoid drillsites, roads and other developed areas.

INTRODUCTION

In 1977, the Bureau of Land Management (BLM), Canon City District, and Colorado Division of Wildlife (DOW) identified an important elk calving area north of La Veta Pass in Huerfano County, Colorado. During this time, ARCO Oil and Gas Company, a division of Atlantic Richfield Company, was exploring and test drilling a CO_2 gas field in the area. ARCO began planning for the development of the Sheep Mountain CO_2 field to allow for the extraction, purification, and compression for transportation of CO_2 gas to oil fields in west Texas.

The BLM contended that ARCO's operation might adversely affect elk calving on the lease area, and ARCO agreed to participate in an elk calving study. From 1980 to 1985, the lease area was surveyed to determine the potential impacts of CO_2 development on calving elk.

This report summarizes the work conducted on this study focusing on the impacts of the development on calving elk and the methods and procedures used in determining these impacts.

Development of the CO_2 field has required a total of over 30 wells directionally-drilled to depths ranging from 4,000 to 5,000 feet (1,219 m. to 1,524 m.)

below ground. Twenty-nine of these wells are clustered in groups of five or six on five centrally located drill sites. Processing (purification) and compression facilities are installed at each drillsite to handle the gas from the wells. All drillsites and remote well locations are connected by a system of all-weather roads.

STUDY AREA

The study area is located approximately 5 miles (8 km) northwest of La Veta in south central Colorado. The study area includes drillsites 4 and 5 which are located in elk calving habitat. Drillsite 4 is located on public land and drillsite 5 is on private lands (Figure 1). The topography of the area is varied, including five major mountains and the surrounding foothills, ridges and lowlands. Elevations vary from about 7,000 ft. (2,134 m.) to above 11,000 ft. (3,353 m.). The region has an arid to semi-arid continental climate, with relatively cold winters and short, hot summers. The habitat of the study area is complex with five major vegetation types present (Figure 2).

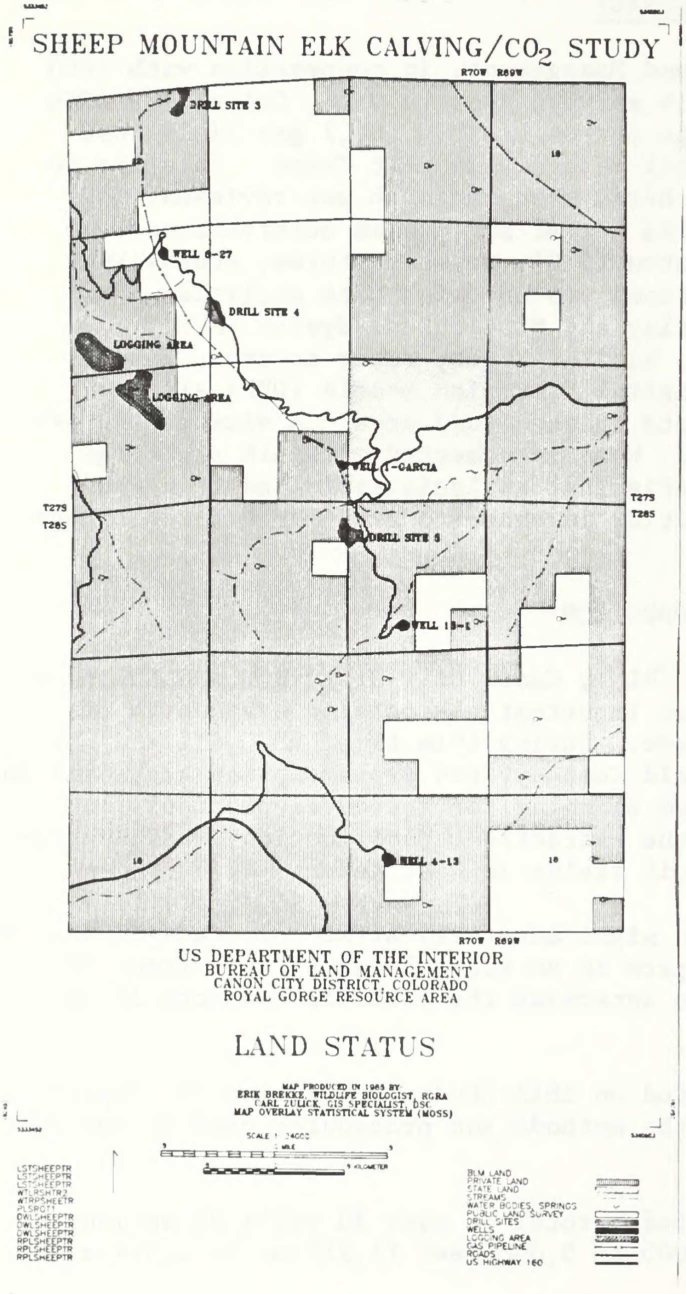


Figure 1. Sheep Mountain Elk Calving Study Area

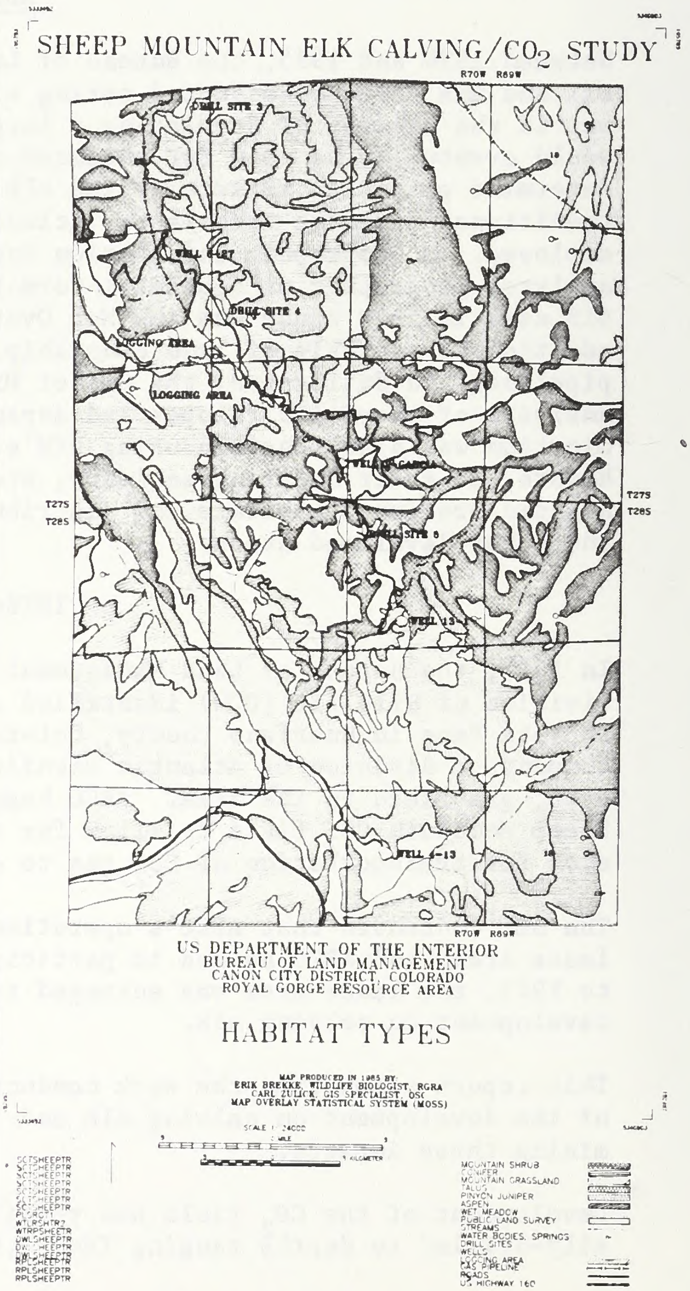


Figure 2. Habitat Types in the Study Area

Mountain grasslands exist on the lower, less steep slopes with deep soils. The mountain grassland habitat type can be segregated into the shortgrass subtype and the wet mountain subtype. The shortgrass subtype is one of the more common vegetative types in the study area occurring in pockets at both high and low elevations. The wet meadow subtype constitutes a small acreage within the study area; however, production capability of meadow sites is extremely high, making them very important foraging areas for elk. The mountain shrub habitat type is dominated by oakbrush and is found on the lower mountain slopes and foothills. The pinon-juniper type occurs in the foothill areas of the study area, generally below the mountain shrub type. The aspen habitat type and conifer type occur in isolated populations at higher elevations.

STUDY METHODS

Aerial Surveys

Aerial surveys were made from fixed-wing aircraft and helicopter. A total of 30 flights were made during the May-June study period from 1980 to 1985. A fixed-wing aircraft was used on eight occasions early in the study period when large groups of elk were in open, relatively flat terrain. Helicopters were used once elk moved into more dense habitats. A total of 22 helicopter flights were completed during the study period. Most aerial surveys were flown between sunrise and 2 or 2½ hours after sunrise, for a total of 65 hours or an average of 2.1 hours per flight. All flights had two to three wildlife biologists as observers. During aerial surveys, sightings were recorded onto topographic maps with notes on seperate forms as to numbers of elk, habitat types, sex, and age.

Ground Surveys

Ground surveys were used to verify aerial survey data as well as check areas not surveyed from the air or where the canopy was too dense to provide adequate visibility from the air. Biologists traveled to areas where elk had recently been seen from the air, usually the same or the preceding day. One to four biologists walked through an area observing tracks and droppings, and stopping from time to time at vantage points to look for elk. The observers counted and, if possible, classified them by sex and age, and tried to evaluate the behavior of adult females to determine whether calves were in the vicinity. A total of 108 work-days (860 hours) were devoted to ground surveys during the 1980 to 1985 period.

Determining Effects of CO_2 Development on Calving Elk

Due to the volume and complexity of the information collected, a computerized approach was used to analyze data collected for this portion of the study. A Geographic Information System (GIS), which captures, stores, and analyzes geographic or spatial information, was selected to complete data analysis. An automated GIS performs the same types of map manipulation and analysis as are currently done by hand. The GIS used in this study was the Map Overlay and Statistical System or MOSS. MOSS, as with most GISs, consists of three basic subsystems. These are data entry, data analysis, and data output, including graphics.

Data entry (digitizing) is the process of converting map data into computer data by tracing a map electronically. The Analytical Mapping System (AMS) was used to electronically encode point, line, and polygon information represented on a map into geographic coordinates. As data was electronically traced, subject information (drillsite names and vegetation types) was added so that the GIS data base contained not only the points, lines, and polygons but subject information as well. Several map themes were digitized for this study including habitat types; water sources; ARCO facilities (including roads, drillsites, pipelines, and auxillary wells); land ownership; public land survey and elk observations for May and June of 1980 through 1985. Elevation data, which was used to derive slope, aspect, three-dimensional perspectives and viewsheds already existed in a digital format as a Digital Elevation Model (DEM) and was purchased from the Geological Survey (USGS). Once captured in the computer, the data was visually displayed on a graphics CRT and manipulated with analytical programs in MOSS. Over 170 analysis commands were available in MOSS that performed operations ranging from simple area and distance calculations to more sophisticated cartographic modelling. MOSS had the capability to do analysis in both vector and raster (cell) environments. The most complex functions were performed in the cell environment. The analysis done for this study and the commands used included:

1. Acreage calculations of habitat types and land ownership (Area Command).
2. Mileage summaries of roads, pipelines and powerlines (Length Command).
3. Elk distribution within habitat types (Intersect Command).
4. Elk distribution within 0.25 - 1.50 mile (0.40 - 2.4 km.) zones around drillsites 4 and 5 (Buffer Command).
5. Elevation class of elk sightings (Extract and Intersect Command).
6. Aspect of elk sightings (Aspect and Intersect Command).
7. Slope class of elk sightings (Slope and Intersect Command).
8. Viewshed determination for Drillsites 4 and 5 (Vista Command).
9. Elk distribution within buffer zones compared between years and habitat types (Intersect Command).
10. Elk distribution within Drillsites 4 and 5 viewshed compared between years and habitat types (Intersect Command).

The Gcalcomp and Zeta commands in MOSS were used in preparing cartographic quality maps for use in reports, meetings, and displays:

1. Land Status (Figure 1)
2. Habitat Types (Figure 2)
3. Contour Map (Figure 3)
4. Three-Dimensional View (Figure 4)
5. Drillsite 4 Viewshed, Elk Sightings and Zones (Figure 7)
6. Drillsite 5 Viewshed, Elk Sightings and Zones (Figure 8)

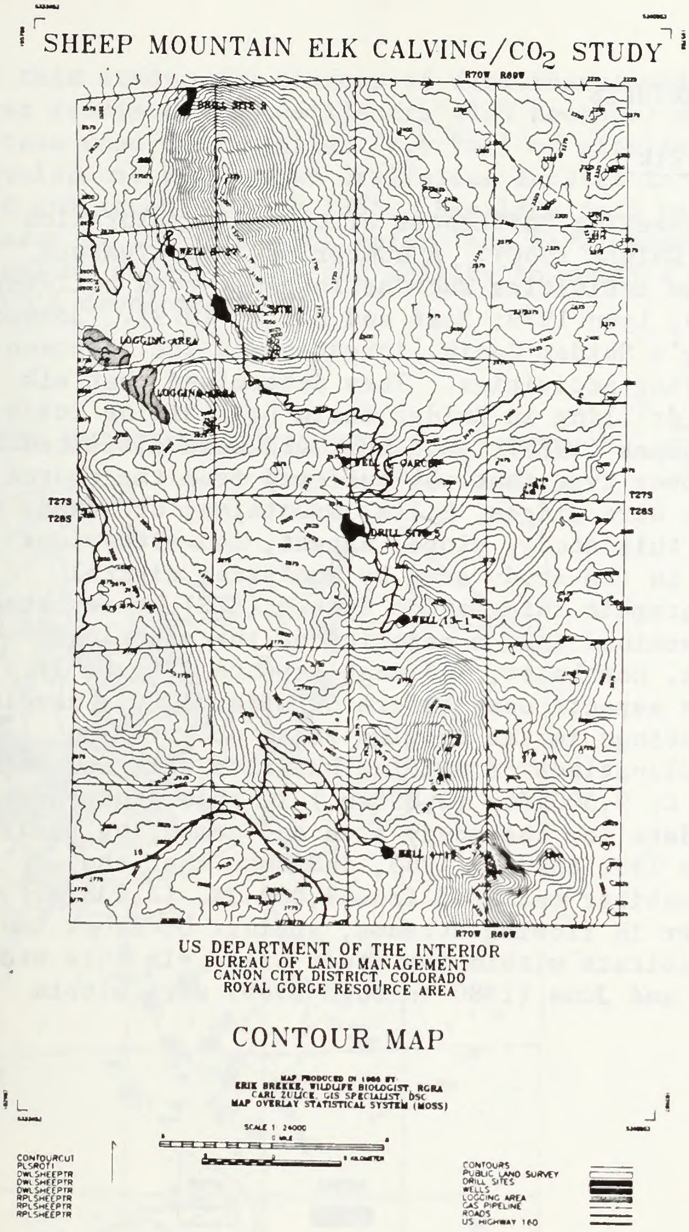


Figure 3. Study Area Contour Map

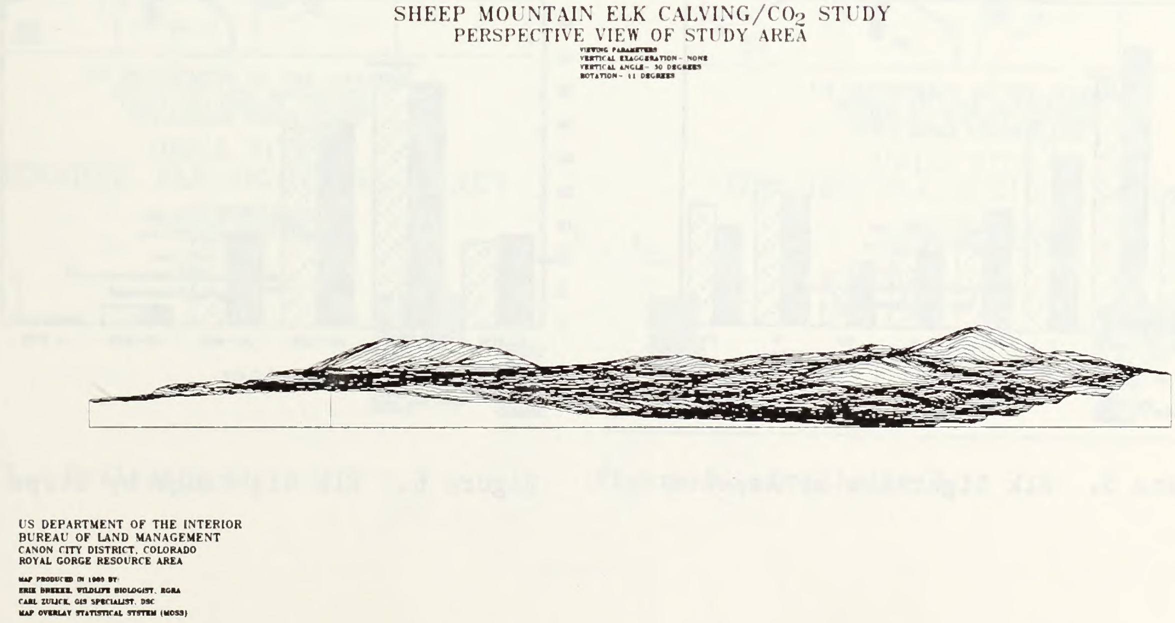

SHEEP MOUNTAIN ELK CALVING/CO2 STUDY
PERSPECTIVE VIEW OF STUDY AREA
VIEWING PARAMETERS
VERTICAL EXAGGERATION - NONE
VERTICAL ANGLE - 30 DEGREES
ROTATION - 11 DEGREES
US DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT
CANON CITY DISTRICT, COLORADO
ROYAL GORGE RESOURCE AREA
MAP PRODUCED IN 1988 BY:
ERIK BREKKE, WILDLIFE BIOLOGIST, RGRA
CARL ZULICK, GIS SPECIALIST, DSC
MAP OVERLAY STATISTICAL SYSTEM (MOSS)

Figure 4. Three-Dimensional View of the Study Area

RESULTS

Effects of CO_2 Development on Calving Elk

Little research has been devoted to assessing influences of oil/gas exploration and development activity on wildlife (Knight 1980). A number of investigators have documented that elk move away from activities such as logging, road building, and activity along roads (Roberts 1974; Lyon 1979; Rost and Bailey 1979). Johnson and Lockman (1981), working in Wyoming's Snider Basin, investigated the response of elk during calving to oil/gas drilling activities. They determined that elk responded to activity associated with drilling in Snider Basin by avoiding roads and the drillsite. Lyon (1975) and Thomas (1979) found that elk were displaced from one cover type to a comparable cover type that was buffered from the source of disturbance by a barrier. Barriers were ridges, hills, mountains, or stands of timber suitable for escape cover. In this study, slope, aspect, and elevations were determined for all elk sightings in the study area by analyzing digital elevation models (DEM) within the Geographic Information System (GIS) as reported in the "Methods" section. It was determined that a majority of the sightings in the calving areas occurred on north, northeast, and east aspects (Figure 5). There was no statistical difference in aspects used before or after ARCO's development. Similarly, most of the elk sightings in the calving areas occurred on slopes of 10-30 percent (Figure 6). Elevations of calving habitats were reported to be from about 8,000 ft. (2,438 m.) to 9,500 ft. (3,896 m.) in this study area (LGL 1980; BLM 1981). Analyzing DEM data for the study area and comparing results with elk observations for May and June 1980 through 1985, indicate that the majority of the occupied elk calving habitat occurred from 8,000 ft. (2,438 m.) to 9,500 ft. (2,896 m.). Surface water in flowing streams, springs or stock tanks, and ponds was common in all calving habitats within the study area. In this study most of the elk sightings between May and June (1980 through 1985) were within 1,320 ft. (402 m.) of water.

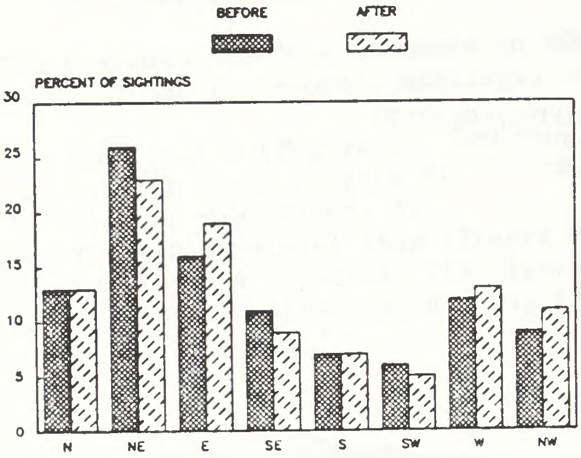


Figure 5. Elk Sightings by Aspects

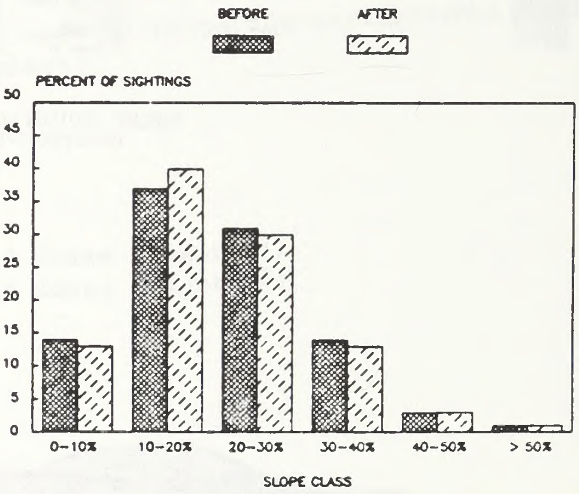


Figure 6. Elk Sightings by Slope

In this study, the sources of disturbance which were located in the elk calving area consisted of two 12-acre (4.8 hectare) drillsites, 12 miles (19.3 km.) of access road, and 6 miles (9.6 km.) of pipeline and powerline (Figure 7 & 8). The development of the two drillsites located in the calving area began in late 1981 and continued through 1985. Baseline data had been collected during the calving season of 1980 and 1981 before any development or disturbances occurred. The baseline data gave us the ability to compare elk distribution before and after ARCO's development.

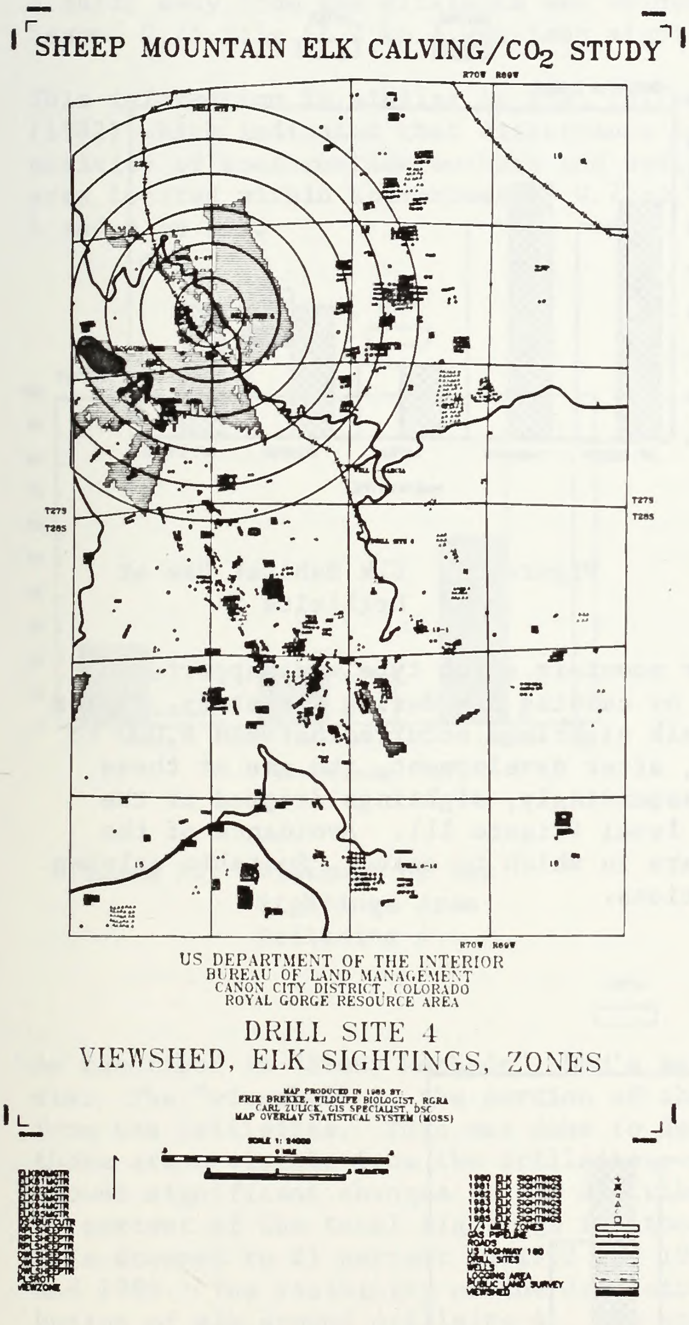

SHEEP MOUNTAIN ELK CALVING/CO_2 STUDY
R70W R69W
T27S
T28S
US DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT
CANON CITY DISTRICT, COLORADO
ROYAL GORGE RESOURCE AREA
DRILL SITE 4
VIEWSHED, ELK SIGHTINGS, ZONES
MAP PRODUCED IN 1985 BY:
ERIK BREKKE, WILDLIFE BIOLOGIST, RGRA
CARL ZULICK, GIS SPECIALIST, DSC
MAP OVERLAY STATISTICAL SYSTEM (MOSS)
SCALE 1: 24000
1980 ELK SIGHTINGS
1981 ELK SIGHTINGS
1982 ELK SIGHTINGS
1983 ELK SIGHTINGS
1984 ELK SIGHTINGS
1985 ELK SIGHTINGS
1/4 MILE ZONES
GAS PIPELINE
ROADS
US HIGHWAY 180
DRILL SITES
WELLS
LOGGING AREA
PUBLIC LAND SURVEY
VIEWSHED

Figure 7. Drillsite 4

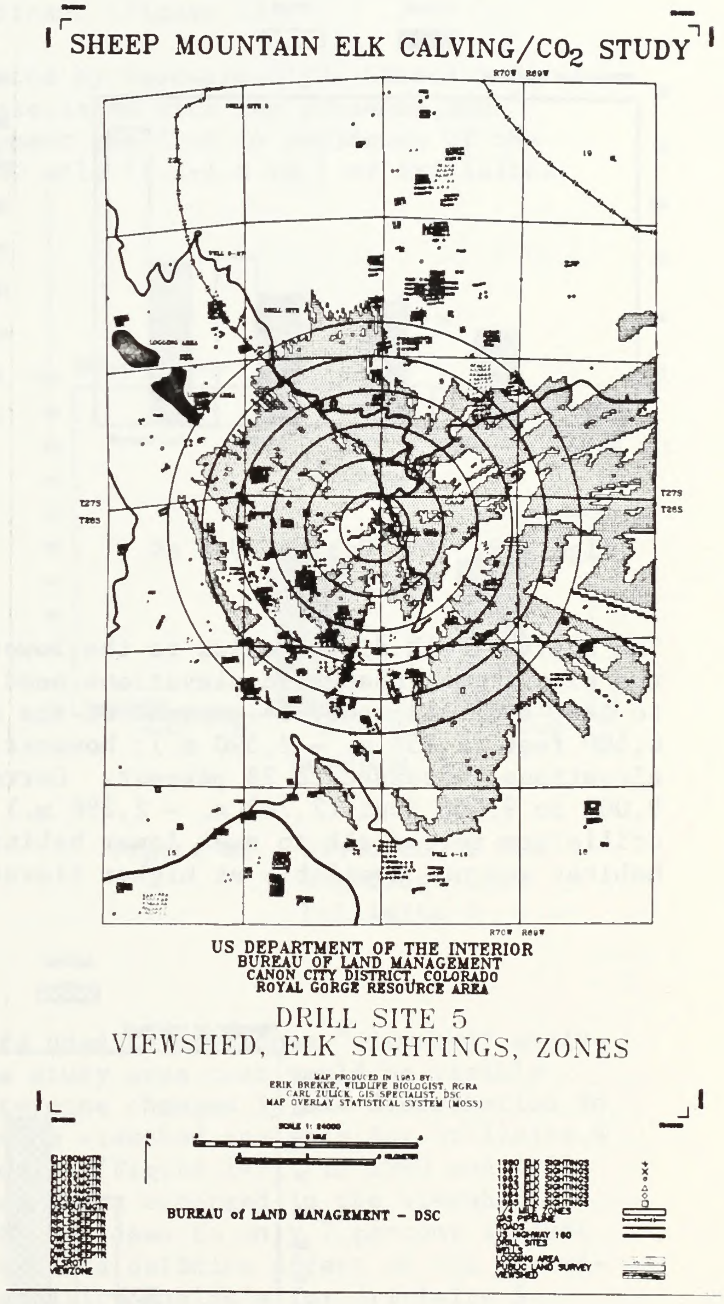

SHEEP MOUNTAIN ELK CALVING/CO_2 STUDY
R70W R69W
T27S
T28S
US DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT
CANON CITY DISTRICT, COLORADO
ROYAL GORGE RESOURCE AREA
DRILL SITE 5
VIEWSHED, ELK SIGHTINGS, ZONES
MAP PRODUCED IN 1985 BY:
ERIK BREKKE, WILDLIFE BIOLOGIST, RGRA
CARL ZULICK, GIS SPECIALIST, DSC
MAP OVERLAY STATISTICAL SYSTEM (MOSS)
SCALE 1: 24000
BUREAU of LAND MANAGEMENT - DSC
1980 ELK SIGHTINGS
1981 ELK SIGHTINGS
1982 ELK SIGHTINGS
1983 ELK SIGHTINGS
1984 ELK SIGHTINGS
1985 ELK SIGHTINGS
1/4 MILE ZONES
GAS PIPELINE
ROADS
US HIGHWAY 180
DRILL SITES
WELLS
LOGGING AREA
PUBLIC LAND SURVEY
VIEWSHED

Figure 8. Drillsite 5

A significant amount of human and equipment construction activity occurred in the area of drillsites 4 and 5 from 1982 through 1985. This resulted in an avoidance of these areas by calving elk. Avoidance of the drillsites caused elk cows to shift habitat use. At drillsite 4, a significant shift occurred out of the wet meadow and aspen types (Figure 9). This shift from preferred calving habitat resulted in a corresponding increase in the use in the conifer and mountain shrub types. At drillsite 5, the change in habitat was less apparent; however, the same pattern was evident - that of a shift to heavier cover types (Figure 10).

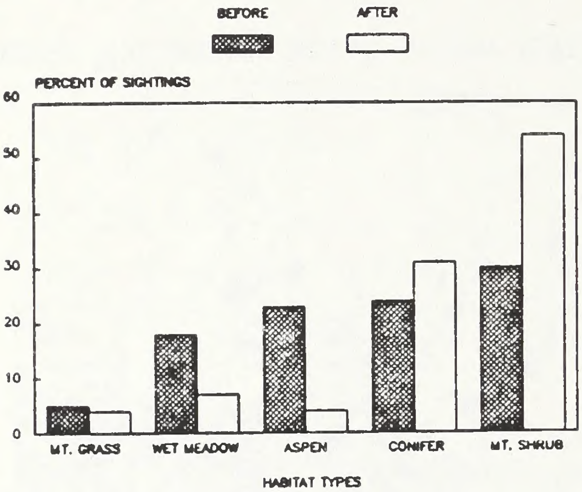


Figure 9. Elk Habitat Use at Drillsite 4

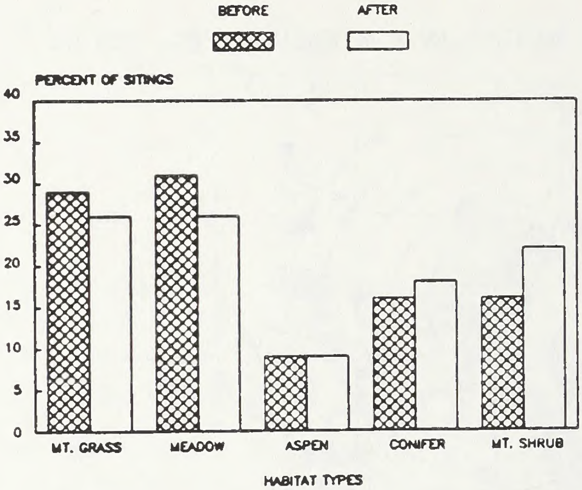


Figure 10. Elk Habitat Use at Drillsite 5

The shift of elk distribution to the lower mountain shrub type was supported by the significant change in elevations used by calving elk during the study. Prior to ARCO's development, 14 percent of the elk sightings occurred between 8,000 to 8,500 feet (2,438 m. - 2,590 m.); however, after development, the use at these elevations increased to 28 percent. Correspondingly, sightings dropped at the 9,000 to 9,500 foot (2,743 m. - 2,896 m.) level (Figure 11). Avoidance of the drillsites forced elk to seek lower habitats in which to calve. Suitable calving habitat was not available at higher elevations.

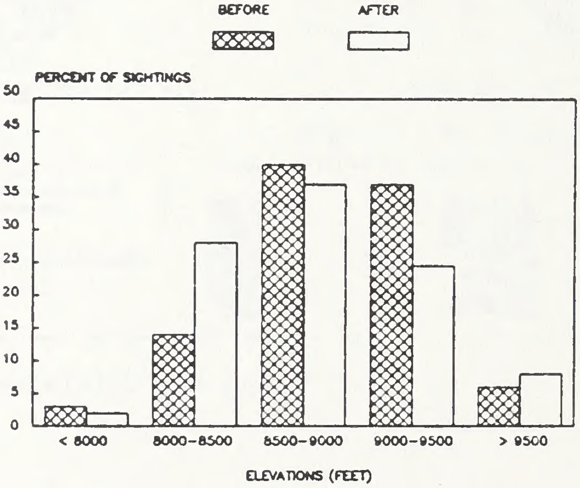


Figure 11. Elk Sightings by Elevation

To determine degree of influence at drillsites 4 and 5, 0.25 mile (0.4 km.) zones around the drillsites out to 1.50 miles (2.4 km.) were developed. Elk sightings were compared within these zones during the 6 years of study. A significant change in distribution was apparent within 0.50 mile (0.8 km.) of drillsite 4 (Figure 12). A number of elk calved within 0.50 mile (0.8 km.) of the drillsite prior to development; however, distribution shifted away from the site when development began. Beyond 0.75 mile (1.2 km.) from the drillsite, differences in elk distribution were less apparent. The same type of analysis was completed for drillsite 5. This drillsite was located in open habitat, and suitable calving areas were located further from the drillsite. A shift away from the drillsite was evident, although change in distribution beyond 0.75 mile (1.2 km.) was less significant (Figure 13).

This information is similar to that collected by Woodward-Clyde Consultants (1982) which indicated that disturbance associated with the presence and activity of construction workers and equipment resulted in avoidance of the area located within approximately 0.75-1.00 mile (1.2-1.6 km.) of drillsites 4 and 5 by elk.

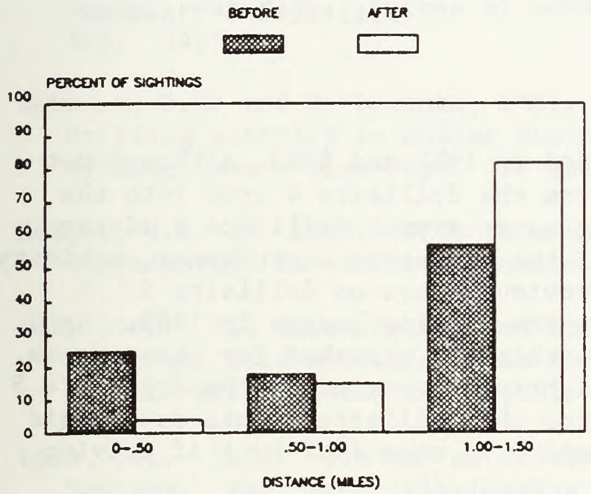


Figure 12. Distance of Elk Sightings from Drillsite 4

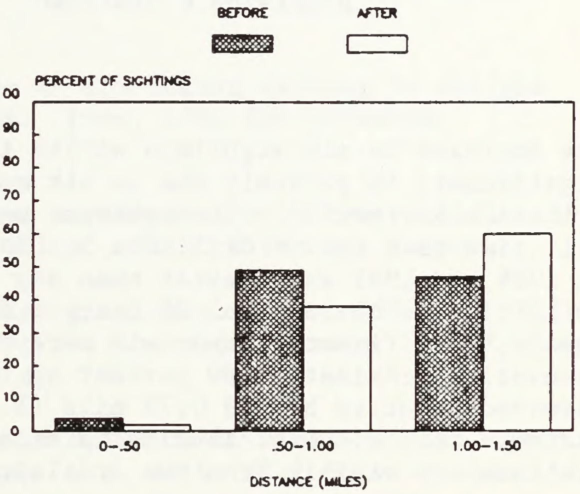


Figure 13. Distance of Elk Sightings from Drillsite 5

As described in "Study Methods", DEM's were used to develop a "viewshed" analysis. The "viewshed" is the portion of the study area that would be visible from the drillsites. This was done to determine changes in elk distribution in those areas visible from the drillsites. The viewshed analysis for drillsite 4 showed significant changes in elk distribution (Figure 14). In 1980 and 1981, 34 percent of the total sightings for those years occurred in the viewshed. This dropped to 21 percent in 1982 and 1983 and down to only 7 percent in 1984 and 1985. The visibility of the drillsite had a definite effect on the distribution of elk around drillsite 4. The visibility analysis for drillsite 5 indicates a similar response (Figure 15).

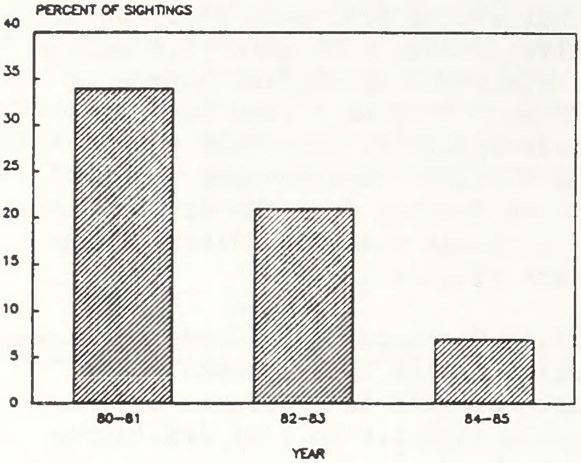


Figure 14. Elk Sightings Within Drillsite 4 Viewshed

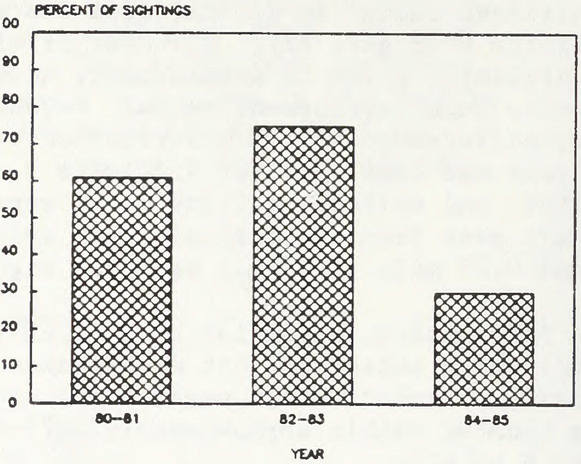


Figure 15. Elk Sightings Within Drillsite 5 Viewshed

The increase in elk sightings within the viewshed in 1982 and 1983, although not significant, is probably due to elk movement from the drillsite 4 area into the drillsite 5 viewshed. Disturbances were much greater around drillsite 4 during this time than around drillsite 5. In terms of the amount of disturbance, activity in 1984 and 1985 was greater than any of the previous years on drillsite 5. A drill rig was operational 24 hours a day during the calving season in 1985. As a result, significantly fewer elk were recorded within the viewshed for these years. However, approximately 80 percent of the elk sightings recorded in the drillsite 5 viewshed occurred beyond 0.75 mile (1.2 km.) from the drillsite. This data would indicate that elk distribution is affected beyond 0.75 mile (1.2 km.) if calving habitats are visible from the drillsite.

CONCLUSION

The data indicates that ARCO's CO_2 development project caused a significant shift in elk distribution around the drillsites located within the calving area. Avoidance of the drillsites forced elk to seek alternate sites in which to calve. Suitable calving habitat was not available at higher elevations, therefore, a shift to lower habitats occurred which resulted in increased use in the mountain shrub habitat type. Significantly fewer elk were recorded within 0.75 mile (1.2 km.) of both drillsites. The viewshed analysis showed that elk were displaced to areas where the visibility of the drillsites was reduced. Elk distribution was definitely affected by the visibility of the drillsite even beyond 0.75 mile (1.2 km.). There were no detectable changes in total population size during the study period. The ultimate significance of elk avoidance in terms of reproductive success and population status is unknown. Studies elsewhere have shown that displacement may affect population numbers and quality of animals within a population. Displacement during calving may be especially critical, causing increased mortality in calves, calf development, disease, accidents, and increased competition.

The substantial improvement in computer systems during the last several years has made it much easier to apply computer technology to the problem of storing, manipulating, and analyzing large volumes of spatial data. Specialized training in GIS system use is necessary in order to efficiently operate the system. Additional lead time is necessary in project planning since digitizing can take some time to complete before analysis can begin. For projects of this nature, much of the analysis could not be completed in given time frames if performed manually, particularly at the level of quality maintained in this project. Some portions of the analysis could have been completed in less time if done manually; however, the output from the automated procedure was necessary for further, more complete analysis. Another benefit of the automated method is that graphics were produced as end products of the analysis. Producing the graphics manually would have been very time consuming and uneconomical. A Geographic Information System is a very effective mechanism for a wide range of wildlife management applications.

LITERATURE CITED

BLM, 1981. Utilization of various habitats by elk and other wildlife during the 1981 elk calving season in the Mt. Mestas and Sheep Mountain area of Huerfano County, Colorado. Bureau of Land Management (Canon City District), Unpubl. Rep. 45pp.

Johnson, B.K. and D. Lockman, 1981. Response of elk during calving to oil/gas drilling activity in Snider Basin, Wyoming. Proc. 1981 Elk Workshop. Wyoming Game & Fish Dept. 14 pp.

Knight, J.E. Jr. 1980. Effects of hydrocarbon development on elk movements and distribution in northern Michigan. Ph.D. Diss., Univ. Mich, Ann Arbor.

LGL, 1980. Elk distribution and movements during calving season, 1980, on the Sheep and Dike Mountain Lease Areas in Huerfano County, Colorado. LGL Ecological Research Associates, Unpubl. Rep. 53 pp.

Lyon, J.L. 1975. Elk use as related to characteristics of clear-cuts in western Montana. In: Proc. Elk-Logging Roads Symp. S.R. Heib (Ed.) Univ. Idaho 142 pp.

Lyon, J.L. 1979. Habitat effectiveness for elk as influenced by roads and cover. J. Forestry 77:658-660.

Roberts, H.B. 1974. Effects of logging on elk calving habitat, Moyer Creek, Salmon National Forest, Idaho. USDA Forest Serv., Salmon Nat. Forest. 22 pp.

Rost, G.R. and J.A. Bailey, 1979. Distribution of mule deer and elk in relation to roads. J. Wildl. Man. 43:634-641.

Thomas J.W. 1979. Wildlife habitats in managed forests. U.S. Dept. of Agr. For. Serv. Ag. Handbook No. 553. 512 pp.

Woodward-Clyde Consultants. 1983. 1982 Elk Calving Study Report - Sheep Mountain CO_2 Project. Woodward-Clyde Consultants Unpubl. Rep. 55 pp.

GEOGRAPHIC REFERENCE AND INFORMATION DATABASE
CENTRAL ARIZONA PROJECT

Michael A. McDonald, Project Cartographer
Bureau of Reclamation
Arizona Projects Office
23636 North 7th Street
P.O. Box 9980
Phoenix, Arizona 85068 USA

ABSTRACT

To the casual observer, the Central Arizona Project (CAP) appears to be just a big ditch. It has been called the largest multi-purpose project in the nation's history. Certainly it is the largest single water-delivery project ever authorized for construction by Congress. This multibillion-dollar reclamation project carries Colorado River water through a mass of concrete lined canals, tunnels, siphons, and pumping stations on a 330 mile journey through the deserts of Arizona to Phoenix and Tucson. The CAP is an engineer's dream coming true. It incorporates the newest technology with the oldest challenge of bringing the water where the people are. The same is true with geo-referenced data and the CAP. The key has been photogrammetry tied to engineering applications. From its humble beginning of collecting digital data (cross-sectioning with a B-8 plotter) to the utilization of photogrammetry's newest technology (analytical plotters, loaded with specialized cross-section, profiling, close-range, and terrestrial software, typical mapping projects relating to the construction of the CAP and six associated large dams, hydrographic charting and control networks utilizing main-frame analytic block adjustments and GPS satellites), photogrammetry applications on CAP projects are a marriage made for the taxpayers pocketbook. If photogrammetry was the key to the bank, we needed a bank to make deposits and withdrawals. We see GIS technology as our bank.

1. INTRODUCTION

The Bureau of Reclamation (Bureau) is in charge of building the CAP. It has been called the largest mult-purpose project in the nation's history. Certainly it is the largest single water-delivery project ever authorized for construction by Congress. Outside of the west, very few people have ever heard of this Bureau quietly tucked away within the Department of Interior. The 83-year-old organization - with 8,300 employees and an annual budget of nearly $800 million - was founded in 1902 and is predicated to water reclamation and service to the 17 western states. Reclamation is the embodiment of the West's history - not just gunfighters or Indian wars. Monumental dams - Hoover, Grand Coulee, Glen Canyon, and others - have spawned magnificent, life-blood reservoirs and the power needed to run the great cities of the West. California's San Joaquin Valley, Washington's Upper Columbia River Basin, and Arizona's Salt River Valley are children of these vast projects. From homestead times, no federal organization has contributed more to Western life than the Bureau of Reclamation.

2. CENTRAL ARIZONA PROJECT

2.1 THE CAP: LIQUID ASSETS FOR ARIZONA

In March 1985, the first gallons of what will eventually be a 330-mile long ribbon of life-sustaining water began flowing into central Arizona. It traveled through mountains, under dry river beds, and across Arizona's parched western deserts toward the state's interior. The water from the Colorado River is destined for use by the people of central and southern Arizona in homes, on crops, and for industries. It is being delivered by the Central Arizona Project, or CAP, designed and constructed by the Bureau of Reclamation. This project has been well over 40 years in the making with its first proposals presented in the mid 1940's. Authorization for the project did not occur until 1968. And construction finally commenced in 1973.

2.2 HOW DOES THE SYSTEM WORK?

A 330-mile long series of open canals, inverted siphons, 14 pumping plants and tunnels will form the CAP water conveyance system. Colorado River water will be pumped from Lake Havasu at a point bout 15 miles north of Parker, Arizona. The Lake Havasu Pumping Plant houses six pumps capable of raising 3,000 cubic feet of water per second up the side of the Buckskin Mountains. The water passes through twin pipes sloping 2,600 feet (824 feet vertical) to the portal of the Buckskin Mountains Tunnel. The 6.8-mile-long tunnel has an inside diameter of 21 feet. The water will flow east and south through Arizona to the southern boundary of the San Xavier Indian Reservation south of Tucson. Along the way the water will be lifted almost 2,900 feet in elevation. Power to run the pumps will come from the Navajo Generating Station near Page, Arizona and from hydroelectric energy generated at Hoover Dam. In addition to these features, construction of four dams and modification of two others has been authorized for additional water conservation, flood control, regulation, sediment control, and other purposes. New dams are planned for the Agua Fria River northwest of Phoenix, the Verde River northeast of Phoenix, on the Gila River east of Florence, and in western New Mexico. Two existing dams on the Salt River east of Phoenix will be modified for flood control, dam safety, and additional water conservation. The reservoirs behind these dams, new or existing, have the potential to greatly expand water-based outdoor recreation in a state where water provides a welcome relief from the sun-baked summers.

2.3 ENGINEERING FEAT - ENGINEER'S DREAM

Central Arizona, its people now in the millions, needs the water to help it meet the demands of expanding population and industry. The additional water will also help reduce the use of ground water and extend the life of that resource. The arrival of Colorado River water will be an epochal event - a triumph of engineering that will help preserve and expand the human presence in an inhospitable, semi-arid desert. "The CAP is an engineer's dream coming true," said Ed Hallenbeck, manager of the Bureau's Arizona Projects Office in Phoenix. "It incorporates the newest technology with the oldest challenge of bring the water to where the people are."

3. GEO-REFERENCED DATA AND PRODUCTS

3.1 COLLECTION OF DATA (1970 TO 1985)

Before construction of the CAP started in 1973, someone had to sit down and plan out on a map the route to be used to take water from the Colorado River and transport it to Phoenix and then on to Tucson, Arizona. Before the first structure or the first mile of canal was dug, or for that matter, the land bought or transferred, someone had to go out and survey first. Owing to the scale of this project, millions of geo-referenced data points have been generated. Early surveys involved cadastral and property surveys, construction sites, and surveys to support planning groups and environmental studies. To aid canal construction, centerline stationing, control networks, and cross-sectioning were initially accomplished by survey methods. Cross-sectioning is used to record original ground, structure design (canal, pumping plants, inverted siphons, tunnels, gates, bridges, wildlife crossings, and check structures), and earthwork quantities used for design, and payment for earth moved at canal, siphon, borrow, or construction sites.

In 1974 a Wild B8-S was purchased to assist in cross-sectioning and to produce highly accurate large scale maps (1" 50' and 1" 100'). To date over 700 maps have been produced from the B8-S. Large scale maps (1" 200' and 1" 400') were contracted out and cover the 330 miles of canal and associated dam features. In 1983 an APPS-IV analytical plotter, loaded with specialized cross-section software was purchased to automate the cross-sectioning process. The amount of data increased from approximately 14 points (survey method) to 25 points (B8-S) to 60-80 points (APPS-IV) for every cross-section at 100 foot intervals on the 330 mile canal.

Using survey and photogrammetric methods, additional geo-referenced data and products have been generated. Some of the more important are: drill-hole coordinates, geologic strata coordinates, profiles, canal alignment, dams and structures positioning, section lines, rights-of-way (roads and transmission lines), distance and area measurements, and reservoir capacities.

Maps relating to land management and classification, environment, terrain (subsurface and surface), geological (bedrock and foundation conditions), archaeological, hydrography (watersheds), vegetation, slope and aspect, ground water conditions, and composite mapped information for public meetings have been generated.

To complete an overall control network around the CAP and the six associated large dams and to reduce the need of field control networks, a fully analytical triangulation system was put into place. A PUG 4 and a K&E Monocomparator were purchased. The GIANT analytical block adjustment program was acquired from the USGS and placed on our main-frame CDC 6400 computer in Denver. We now have the capability to geo-reference all of our data through our control networks by a series of large block extensions. This should help in the future by allowing for the rapid generation of new digital data for as-built construction, canal leakage, and land subsidence monitoring. The system is being further strengthened by the utilization of the NAVSTAR Global Positioning System (GPS). The satellites are used to calculate the position coordinates and elevations (first and third order NGS control points) around our dam projects and along the CAP canal subject to land subsidence.

New projects and systems newly acquired or just starting include the state-of-the-art survey equipment and field to office data communication and reduction. Subsurface (caves, chambers, and penstocks) mapping and underwater hydrographic charting are being accomplished by our Survey Section. Utilizing the APPS-IV, two Wild P-32 Terrestrial cameras, and specialized software we will be able to produce close-range and terrestrial digital data products. The data will first be used by our geology and design groups at the six dam sites. Proposed uses include geological studies, cliff and abutment mapping, historical record, spillway studies, borrow site mapping, archaeology studies, powerhouse infra-structure monitoring, pipe roundness acceptance tests, and dam structure deformation studies. This year the APO's HP 1000 was interfaced to the APPS-IV, the Wild B8-S, a CalComp 965 Plotter, and the K&E Monocomparator. The system can communicate with our Survey Section, the APO's VAX computers and the IBM PC-AT workstations, and our CDC 6400 in Denver. Our B8-S is being automated with model set-up and digitizing capabilities. We have just acquired two AS11-AM Analytical Plotters from the Defense Mapping Agency. We expect them to be on-line by mid-1986.

3.2 FIFTEEN YEARS OF DATA

The APO management recognized a need for a mechanism to better organize and manage geographic data, maps, coordinates, measurements, soil classifications, etc., required by the APO staff. Management identified to basic needs with respect to geographic information. One is to improve the efficiency and timeliness of data collection and analysis using electronic aids. The other is the need to transfer data quickly and accurately between the groups that need them. Currently this is strictly a manual process, with many costly time delays and duplication of effort. Both of these needs have been amplified by the recent acceleration of CAP completions and delivery schedules.

Management wanted a system that would provide efficient data storage and transfer between branches to assist in meeting deadlines and provide an effective data base for planning, management, and operations. Delays were encountered because data required by different branches could not be transferred digitally. Often automated data had to be re-entered because of hardware and system incompatibilities. The data, by its nature, is cumulative. Current analog recording methods are compounding data management problems. Development of an integrated data base, a geographic information system, to help solve these problems was proposed.

4. GRID/CAP

4.1 BACKGROUND STUDIES

During 1982 and 1983 preliminary research was conducted by the ADP office and the Project Cartographer for the APO. An operational system run by the

U.S. Fish and Wildlife Service in Fort Collins, Colorado was visited. They had been mapping the National Wetlands for several years using the Map Overlay and Statistical System (MOSS) software. They were collecting data using digitizing tables and an APPS-IV Analytical Plotter and the Analytical Mapping System (AMS) software. The software and the database existed on Data General Computers. In the spring of 1983 the GIS request for the Bureau of Reclamation - Sacramento office was reviewed. The system contained a proprietary software package called ARC/INFO.

In the spring of 1984 a GIS seminar was held at the APO. Two studies, independent of each other, were contracted out to address the possibility of a GIS program at the APO. APO personnel started attending IDCCC meetings. In October approval was given for a GIS Pilot Plan. Inquiries were made of all of the Government agencies using GIS technology as to hardware and software configurations. Contracts were awarded and a system manager was hired. We are in the process of building the database around one of the dam sites. The pilot will become a model for the other five sites. The pilot will be demonstrated during January 1986. The final demonstration will take place in October 1986. A final report will be issued in December 1986.

4.2 ALTERNATIVES CONSIDERED

Examples of factors that were considered include: utilization of existing APO hardware (APPS-IV Analytical Plotter, CalComp 965 Plotter, Tektronic digitizing equipment, and HP and DEC terminals, printers, and pen plotters), public domain software (AMS/MOSS) versus proprietary "turn-key" software (ARC/INFO), software costs, which computers did the different software packages reside on, computer system costs, use of a super microcomputer network, integration with the future Bureau-wide CADD system access to existing data holding on HP-1000, VAX-750, and CDC 6400 computers, interface to a newly acquired GEOMIN system (residing on a HP-9836 computer), and an interim AUTOCAD system (residing on IBM PC-ATs), and integration with future ADP-wide hardware procurements. The GIS will be interfaced to these systems in order to ensure that there is no duplication of effort or resources and to provide the users with a central point of access to the diverse data holdings.

By the nature of our projects, we wanted a system that could produce the high accuracies needed to support design, construction, and other engineering-related activities. If the system could interface to our APPS-IV Analytical Plotter we could eliminate the need to redigitize maps. This would give us the high accuracies produced from stereo models. The system would have an arc-node and pologon data structure. It would have to support table digitizing and single photo resection. It must be a topographically-defined system and must include vertical map capability. All of this plus the normal requirements associated with a GIS.

The system should enable the Bureau to exchange data between Bureau projects, the Central Arizona Water Conservation District (CAWCD), the Arizona State Database, other sister agencies in the Department of Interior (USGS, BLM, FWS, NPS, and BIA), FS and SCS, DOE, EPA, Bureau of Census, and DMA, COE, and ETL within the Department of Defense.

4.3 SYSTEM CONFIGURATION

In conversations with personnel at ETL concerning the APPS-IV, we learned of the Terrain Analyst Work Station (TAWS). They had designed a GIS based on the public domain software AMS/MOSS. AMS allows the user to build and edit geographic data bases. It supports aerotriangulation of source photography; stereoscopic and monoscopic digitization; and data base management. MOSS is an interactive spatial analysis system for manipulating geographic data files. It provides the primary product generation and analysis subsystem for TAWS. ETL personnel suggested a system configuration similar to theirs. A letter of technology transfer was signed between the Bureau's APO, ETL and a private vendor of the software.

Hardware, consisting of a Hewlitt-Packard 9920T bundled system with a UNIX operating system, FORTRAN 77 compiler, graphics capability, and mult-user functions, was purchased. The computer is a desktop 32-bit machine. It was purchased with 3.02 Mbytes of memory and is expandable to 7 Mbytes. The system also includes two 55 Mbyte disc drives, system and digitizing station graphics CRTs, and a CalComp 9100 Digitizing Table. The equipment is being interfaced to existing APO hardware; CalComp 965 Plotter, APPS-IV Analytical Plotter, HP printers, plotters, and terminals, and the HP 1000 Computer. Any software enhancements or code conversions will be made available to the Bureau from ETL as long as it is of an unclassified nature.

4.4 APPLICATIONS AND POTENTIALS

A GIS stores, displays, retrieves, and analyzes spatial data. Many different disciplines (engineering, planning, hydrology, geology, etc.) are able to make use of various types of spatial data. A flexible system has been built which provides a means of extracting only that data which is pertinent to their specific needs. Since these investigations utilize maps, aerial photography, and other types of remote sensor data, accurate measurements and data integration techniques are vital to the success of our projects. The GRID-CAP system will feature digitization, both from a CalComp 9100 Digitizing Table and the APPS-IV, interfaced to and through several host computers running the AMS/MOSS/MAPS GIS software. The APPS-IV will enable the analyst to view images in stereo, thus enabling the operator to accurately identify, locate, and measure features and their dimensions on the earth's surface. Interpretation, mensuration, and digitization can be carried our simultaneously, thereby reducing the number of individual steps and the time required to complete a project.

The software controls all setup, digitization (table and analytical plotter), and data manipulation for the system. By enabling the user to automatically integrate and systhesize multiple data sets by means of scale change and digital overlays, correlations can be developed among data sets that would not be readily achievable by manual methods. Other functions, such as database management, display, analyzation and hard-copy output, are easily handled. With GRID-CAP, it will be possible for analysts with no formal cartographic or photogrammetric training (e.g. engineers, planners, geologists, etc.) to be directly involved in developing and exploiting digital databases.

The GRID/CAP System will be capable of exploiting and manipulating many types of remote sensor data. It will permit multiple overlays to be digitized simultaneously. Also, the analyst will have the ability to interpret and record data concurrently. The system can create digital elevation model (DEM) data or collect point (node) data to create contour maps. The system could then display this contour data in raster format as a three-dimensional model of the landscape. A major advantage of the system will be its ability to collect data in geograhic coordinates. It will provide a detailed, spatial, geoencoded, digitals, and geographic database.

Major GRID/CAP applications are: dam site selection (geologic structure, lithology, seismic data, drill hole data, and reservoir studies), corridor selection (right-of-way, canals, roads, and power lines), construction monitoring (aerial, close-range, and terrestrial data collection), earth/work calculations, erosion/sedimentation studies, watershed studies, slope stability studies, terrain simulation, survey applications, flood damage assessments, land cover acreages, historical change, ground water studies, monitoring temporal land use changes, well and canal water rights, projection of canal leakage locations, monitoring land subsidence, security, and on-going operation and maintenance of the CAP and its associated dam projects.

5. BENEFITS AND SAVINGS

A Geographic Information System will control large volumes of engineering and coordinate information being generated, stored, and transferred and will provide this data to other "user" branches in an efficient and timely manner. At the same time it will develop a data base to support future planning, management, and operations. Standardization and automation of the information will ease the transfer and responsibilities to the CAWCD. A GIS is the only alternative that will meet the geo-referenced needs that have been amplified by the recent acceleration of CAP completions and delivery schedules.

GRID/CAP will allow the APO to meet its legal obligations for mandatory reporting and allow it to satisfy Freedom of Information Act requests. GRID/CAP will make data available to: the Bureau, other Department of Interior and Federal agencies, state and local governments, public utilities, and all of the water user districts being supplied by the CAP. Savings in the order of $3-4 million are anticipated primarily the result of speeding up support activities for the site selection, bid acquisition, construction, and permitting processes.

If the CAP is an engineer's dream come true then new technology must be used to meet the challenge of building such a large system in such a short time. Two of the keys have been photogrammetry and the collection of geo-referenced data tied to engineering applications. These applications on CAP projects are a marriage made for the taxpayer's pocketbook. If geo-referenced data and photogrammetry are the keys to the bank, we needed a bank to make deposits and withdrawals. We see GIS technology as our bank. Utilizing GIS technology married to photogrammetry and engineering applications completes our full-service banking system.

INTEGRATION OF A RELATIONAL DATABASE MANAGEMENT SYSTEM WITH MOSS

Patrick Dempsey
3CI
155 W. Harvard, Fort Collins, CO. 80525

The InFoCen®-MOSS Connection merges the merits of the relational database management system (RDBMS) and the geographic information system (GIS). The connection offers a unique advantage to users of the GIS package, which typically lacks RDBMS capabilities. By combining the attributes of the RDBMS and GIS, the InFoCen®-MOSS Connection allows management of both textual and digitized data.

The InFoCen®-MOSS Connection consists of a menu-driven InFoCen® command (MOSS) that provides 10 functions. These multipurpose functions include generating MOSS point maps from InFoCen® maintained data, as well as generating InFoCen® reports from MOSS map displays. Thus, InFoCen® effectively supports managment of textual data, while MOSS provides management of digitized data, including graphical display capabilities in the form of maps.

3CI has experience interfacing InFoCen® with other GIS packages. Of particular interest and utility is an interface that reads in digitized data and produces high resolution maps using 3CI's device independent menu-driven graphics software.

INTEGRATION OF A RELATIONAL DATABASE MANAGEMENT SYSTEM WITH MOSS

Patrick Dempsey
3CI
155 W. Harvard, Fort Collins, CO. 80525

The InFoCen®-MOSS interface merges the merits of the geographical information system (GIS) and the relational database managment system (RDBMS). The interface offers a unique advantage to users of the GIS package, which traditionally lacks RDBMS capabilities. By combining the attributes of the GIS and RDBMS, the InFoCen®-MOSS Connection allows managment of both digitized and textual data.

The InFoCen®-MOSS Connection consists of a menu-driven InFoCen® command (MOSS) that provides 10 functions. These multipurpose functions include generating MOSS point maps from InFoCen® maintained data, as well as generating InFoCen® reports from MOSS map displays. Thus, InFoCen® effectively supports management of textual data, while MOSS provides management of digitized data, including graphical display capabilities in the form of maps.

Other benefits of the InFoCen®-MOSS Connection include:

- New, useful, and timely information can be generated combining textual and GIS data.
- Many previously impossible tasks can be accomplished wihtin reasonable times and costs.
- Non-programmers can use the functions.
- The new functions can be performed through easy-to-use menus.
- The interface has no adverse affects on existing InFoCen®databases and software, or on existing MOSS projects and software.
- The connection provides for minimal data redundancy.

InFoCen®

InFoCen® is a set of integrated information management tools based on a relational database management system. Specifically addressing the IBM endorsed information center concept, InFoCen® provides a series of end user software modules which can be implemented on a building block approach.

InFoCen®'s relational query capability (NSQL) provides for simple as well as complex Boolean logical expressions for information retrieval and report generation. This retrieved information can be presented in virtually any format desired including the display of subsets of records and the display of selected items from these records. Relational commands allow the user to relate records in one dataset to related records in another dataset. InFoCen®'s basic statistics capability provides for standard statistics including MIN, MAX, AVE, SUM, and Standard Deviation for subsets of records. Virtual items can be defined by the user to create new items for each record. These virtual items may be computations based on one or more items in the database record. Data in selected subsets may be exported to an external ASCII disk file. This exported file may be any combination of items from the database record description and formatted in a number of ways.

The EXPORT facility is extremely useful for passing subsets of data from InFoCen® databases to external files which are then available for other software systems to access, with little or no traditional application programming required.

An InFoCen® database resides on a single disk file, regardless of the number of datasets (tables) or data items. Because all data structures (datasets, directories, cross-reference tables) are contained on a single file, disk management is handled internally by InFoCen®. A directory/dictionary is established which contains approximately 65 parameters about a dataset and corresponding data items. The directory is actively updated during database operations.

Records are hashed into a dataset and may be partially or completely inverted in cross-reference tables depending on how the items will be searched. The hashing routine uses an algorithm which is independent of the number of records in a dataset. When a record is placed in a hash table, its position becomes its record number. These record numbers act as switches within the cross-reference tables. A bit vector is maintained for all inverted items and is used to keep track of records with common characteristics. Complex boolean retrieval expressions "map" corresponding bit vectors to create a run time bit map to a subset of records. The records are not actually accessed until they are printed or displayed. The data remains independent of the inquiry. The criteria (bit map) for a subset of records resides in main memory, but the records themselves remain in the relational table.

A threaded binary search tree may be maintained by the user on any inverted item. This retrieval method facilitates single record retrieval, sorted retrievals and proximity searching. The tree is completely optional and, when utilized, is system maintained.

Items which are not inverted are searched and retrieved using blocked sequential scanning. This technique, although slower than hashing, may be used on items which are searched infrequently, thereby saving disk space.

Records may be stored interactively (real time) or in a batch mode. In either case the user may verify the data against predetermined editchecks.

The InFoCen®-MOSS Interface

A thorough understanding of InFoCen® is not necessary for describing the process of data manipulation. It is important however, that a number of criteria are met before any relational DBMS will be a useful complement to the MOSS system.

First, the DBMS must have an IMPORT facility which provides an easy mechanism for getting data into the system.

Secondly, the DBMS must have a query capability to effective perform appropriate data analysis.

The DBMS must be able to EXPORT data to the MOSS system without alot of user manipulation.

Both systems should reside on the same computer.

Using The InFoCen®-MOSS Interface

The InFoCen®-MOSS Connection is accessed via the InFoCen® command called MOSS. If you wish to do any application work with the InFoCen®-MOSS capabilities, enter into InFoCen® first, then access MOSS via InFoCen's MOSS command.

Entering the MOSS command produces a scrolled menu of InFoCen®-MOSS functions. The menu will appear on the screen as follows.

```
COMMAND?
moss

PLEASE CHOOSE ONE OF THE FOLLOWING MOSS OPTIONS
ENTER:

(M)  TO CREATE A MOSS MAP ADDFILE FROM AN INFOCEN SUBSET
(E)  TO EXPORT A UNIQUE IDENTIFIER LIST FOR SELECTION FROM A MOSS MAP
(S)  TO CREATE AN INFOCEN SUBSET FROM AN EXPORTED MOSS SELECTION LIST

IN ADDITION,
THE FOLLOWING OPERATIONS ARE
AVAILABLE THROUGH THE CLI COMMAND                ENTER:
_____________________________________            ______________

ENTER A SINGLE CLI COMMAND                       CLI
TO REMAIN IN CLI FOR MORE THAN ONE COMMAND       CLI X :CLI
CREATE A PROJECT FILE                            CLI X DATABTEST
RUN MOSS                                         CLI MOSS
GET A DIRECTORY LISTING OF PROJECT FILES         CLI DIR +.DT
DELETE A FILE                                    CLI DELETE filename
VIEW THE CONTENTS OF A FILE                      CLI TYPE filename
```

Creating A Moss Addfile

MOSS generally supports three types of maps: point, line, and polygon. Line and polygon maps are created through digitizing. Point maps can be created without digitizing. A point map can be created by MOSS from a file of data that need only contain attribute information and coordinate information. This information must reside in a specific MOSS addfile format. Option M generates a file of InFoCen®-maintained data in the MOSS addfile format.

The M option requires that you create a subset of the desired records for analysis using the appropriate InFoCen® command (i.e. SELECT, RETRIEVE, COMBINE). After supplying additional information shown, a MOSS addfile will be created. This addfile can be used directly by the MOSS ADD command to create a MOSS map. This option will produce a one-to-one relationship between InFoCen®records and MOSS map points.

Exporting A Unique Identifier List

Option E of the InFoCen®-MOSS functions allows you to export an InFoCen® subset of records to be plotted on a MOSS map. When a subset has been exported using this option, an Active Id(s) can be created in MOSS which can be WINDOWed and PLOTed. The exporty files are used as input to subsequent MOSS SELECT FROM commands.

Before using this option, you must have created the subset of records you wish to be plotted. After selecting the "E" option you will be prompted for the export file name, the subset name, and the InFoCen® item name of the unique record identifier.

Using A Moss Selection List To Create An InFoCen®Subset

While in MOSS, you may wish to examine the textual data related to a MOSS map displayed. Option S allows you to create an InFoCen® subset from an exported MOSS selection list. Before using this option, you must export hte Active Id for the MOSS map for which you wish to find the related data in InFoCen®. Exporting the Active Id for the map on the screen will place the point identifiers into an ASCII file.

After you exit MOSS and return to InFoCen®, you may use this option to create a subset from the current InFoCen® dataset based on the values in the MOSS selection list. The resulting subset relates to the map displayed and can be used for further analysis.

Using The CLI Command

All of the previous functions described are executed only after the InFoCen® prompt: COMMAND?. If you wish to use one of the CLI functions listed in the MOSS options menu, you must first enter "QUIT" to interrupt the InFoCen® MOSS command.

To access any AOS/VS CLI command, you may enter "CLI". Once the AOS/VS CLI command is completed, you are returned to InFoCen®.

If you wish to execute more than one CLI process, use the CLI X :CLI option. You will then remain in AOS/VS until you enter "BYE". You will then be returned to InFoCen®.

You may also use CLI to run a MOSS utility program called DATABTEST that will create a MOSS project file. Creating a MOSS project file is analogous to using InFoCen® to create a database. When DATABTEST is completed, you will be returned to InFoCen®.

Any time you wish to run MOSS while in InFoCen®, you may run the MOSS CLI. This CLI will set searchlists and run MOSS. You may then return to InFoCen® by entering "BYE".

Using the F/S +.DT CLI option, you may list the file status of all InFoCen® MOSS files that the AOS/VS security allows. After the file status listing has completed, you will be returned to InFoCen®.

To clean up any files after a session is completed, you may use the CLI DELETE option.

The CLI TYPE option lets you list the contents of the file name you specify.

InFoCen®-MOSS Interface Future Developments

Future InFoCen®-MOSS developments are and will be driven by current and potential 3CI InFoCen® clients. Based on informal surveys of existing InFoCen® and MOSS users it is evident that enhancements to these systems and to their combined functionality is desirable and would be extremely productive. A few of the most asked for are listed below.

Providing a method to keep data in an InFoCen® database and in a MOSS database in sync would make maintenance on the data considerably easier and ensure data integrity.

Other hardware/software environments would be welcomed, specifically UNIX environments.

Enhanced display capabilities in terms of:
- a greater variety of graphics hardware devices
- split screen map display
- map display via InFoCen's MAPS utility

Creation of MOSS line and polygon maps from InFoCen® maintained data.

SOME CAPABILITIES OF MOSS/MAPS APPLIED TO CULTURAL RESOURCE MANAGEMENT

Mark A. Calamia and Daniel W. Martin
Bureau of Land Management
Building 50, Denver Federal Center
P.O. Box 25047
Denver, Colorado 80225-0047

ABSTRACT

The analysis of archaeological inventory information for cultural resource management (CRM) and planning purposes involves two primary aspects: the assessment of archaeological site inventory data and the identification of existing or potential cultural resource and land use conflict areas. This paper presents some specific MOSS/MAPS commands and procedures that aid the federal archaeologists in meeting their analytical needs. Federal archaeologists stand to save time and increase their effectiveness by using a Geographic Information System (GIS) for meeting these work requirements.

INTRODUCTION

Resources such as timber, coal, oil and gas, rangeland, watersheds, etc., all have geographic distributions. A primary concern of land use managers is the quality, quantity, and distribution of these resources as well as the relationships among them. The organizing principle for this process is based on spatial relationships. Cultural Resource Management (CRM) is no exception.

The need for spatial analysis in CRM, in a multiple-use setting, is reinforced by the parent discipline of CRM, Archaeology. Most archaeologists work with three basic dimensions: space, time, and form. The Geographic Information System (GIS) provides a valuable tool for analyzing the spatial dimension of archaeology because it enables archaeologists to perform numerous geographic measurements quickly.

The Bureau of Land Management (BLM) is exploring ways of using GIS and MOSS/MAPS, in particular, to more effectively perform its CRM functions. In this application, the study area included four 7 1/2-minute quadrangles. The study area is in the northern San Juan Basin of northwestern New Mexico and includes a small portion (154,187 acres or about 10 percent) of the BLM Farmington Resource Area. Generally, the environmental setting can be characterized by a gently sloping upland erosional surface, partially covered by sheet sand and and dunes, with badlands exposed where drainages have cut through the upland surface. Ephemeral streams and washes cross the study area. Vegetation is primarily in the form of desert shrubs and grasses.

For the purposes of this study, archaeological site data for a specific cultural period--the Archaic--were selected for analysis. The Archaic period (5,500 BC to to AD 400) represents a hunting and gathering adaptation in the northern San Juan Basin.

The reasons for selecting this particular study area are threefold. First, the BLM Resource Management Plan (RMP) process is being initiated in the Farmington Resource Area. The extraction of coal and oil and gas, in particular, presents a source of possible conflict with cultural resources. Second, the amount of existing archaeological inventory allows for adequate analysis of the acreage counts. About 29 percent of the study area has been surveyed. For this analysis, an inventory level of at least 20 percent was considered ideal. Most resource areas do not have this high a level of inventory for this size area. Third, the majority of the environmental and administrative themes used for analysis had previously been digitized at the BLM New Mexico State Office and Albuquerque District Office, where MOSS/MAPS is currently being used for the management of natural and cultural resources.

In the effort reported in this paper, the survey data base was analyzed to determine areas requiring more inventory to provide a more representative sample of cultural site and environmental data in the study area. Such analysis can be used to indicate precisely where to inventory and where inventory biases are concentrated.

Analyzing archaeological data for BLM requirements involves preparing RMPs and environmental assessments that include Environmental Assessment Reports (EARs) and Environmental Impact Statements (EISs). To meet CRM operation needs, the federal archaeologist must (1) assess the archaeological site inventory data and (2) identify areas of existing or potential cultural resource and land use conflicts.

ASSESSMENT OF ARCHAEOLOGICAL INVENTORY DATA

The BLM inventory structure consists of sequential classes or tiers of inventory (BLM Manual 8100, 1978). Class I inventory is a review and compilation of existing data. Class II inventory is defined as a sampling field inventory. BLM Manual 8100 definition does not, however, address relationships between sampling and spatial analysis because this definition was formed before GIS was developed or imple-mented. Class III inventory is a complete surface inventory of a specified area, i.e., an intensive field inventory. Most of the surveys in the project were conducted at the Class III level as units of intensive survey for several Class II inventories in and near the project area.

The MOSS/MAPS package is capable of using the Class II and Class III inventory data to address the following Class II inventory objectives, as identified in the BLM manual (BLM Manual 8100, 1978).

1. Discovery, recognition, or elaboration of patterns of past human use and occupation of given regions.
2. Determination of the cultural resource potential of an inventory area.
3. Prediction of zones of greater or lesser activity by past human populations.
4. Identification and assessment of the environmental and/or cultural variables, or combination of variables, that form the most accurate predictors of cultural resources.
5. Development of projections of expected density distribution and diversity of cultural resources.
6. Discovery of the range of cultural resource variability within an inventory area.
7. Provision of an objective means of assessing the existing cultural resource inventory.
8. Development of a systematic base for planning decisions concerning cultural resources.

The following MOSS/MAPS procedures were used in preparing the inventory data base for further analysis and in order to determine where future inventories need to be conducted. (All commands are capitalized; MOSS commands are underscored, whereas MAPS commands are not.)

1. MERGE four 7 1/2-minute quadrangles for each environmental or administrative data theme.

2. RASTERIZE to convert to cell format with background and non-background values. A 30 x 30 meter cell size was used to obtain the highest resolution possible.

3. SLOPE OR ASPECT continuous elevation map to produce continuous slope and aspect maps.

4. EXTRACT only the continuous elevation, slope, and aspect maps to assign new values and convert to discrete data classes for CROSSING. Note: Elevation theme was derived from Digital Elevation Models (DEMS).

5. MERGE the archaeological inventory data. The inventory data is at 1:100,000 scale and involved the merger of 32 7 1/2-minute quadrangles (performed at the BLM Albuquerque District Office).

6. BUFFER archaeological point and line inventory data at 1:100,000-scale (performed at the BLM Albuquerque District Office).

7. GENERATE a WINDOW border using UTM coordinate pair data for the four-quadrangle study area. The WINDOW was expanded beyond the edge of the map to create even multiples of the 30 x 30 meter cell size. In this way, each cell map had the exact number of cells, with no rounding error. By enlarging the window, the edge of the map was not obscured by the window frame when viewed on the terminal screen.

8. OVERLAY 1:100,000 BUFFERED archaeological inventory maps with WINDOW border using "intersect" option of the OVERLAY command. The resulting map included only the inventory data for the four-quadrangle study area.

9. RASTERIZE BUFFERED archaeological inventory data to convert to cell format with background and non-background values. A 30 x 30 meter cell size was used to obtain the highest resolution possible. (Cell size must be the same as in Step 2.)

10. EXTRACT to combine all map values into one like classification and assign a new single value to all cells having inventory data.

11. CROSS environmental or administrative data theme with archaeological inventory data to create a new discrete map showing logical intersection of inventoried areas, by subject, as well as non-inventoried areas. The logical operations "AND" and "OR" in the CROSS command were used to assign new values to cells.

12. AREA the CROSSED map to obtain the number and percentage of areas inventoried for each subject of a theme.

Figure 1 lists environmental and administrative themes used for assessing the inventory data. Figure 2 shows the soils data overlayed with the inventory data theme. Table 1 is an area table showing the amount of each soil type intersected or not intersected with survey data.

IDENTIFICATION OF CULTURAL RESOURCE AND LAND USE CONFLICT AREAS

As mentioned above, the federal archaeologist is often required to provide input on long-range planning documents involving a variety of development actions.

DATA THEMES

A THEME IS THE NAME OF A SPECIFIC ENVIRONMENTAL OR ADMINISTRATIVE MAP LAYER USED IN ANALYSIS. ON THE BASIS OF ITS CHARACTERISTICS, EACH FEATURE OR CELL IN A MAP IS ASSIGNED AN IDENTIFIER CALLED A SUBJECT. A SOIL THEMATIC MAP COULD CONSIST OF SEVERAL SOIL TYPES OR ASSOCIATIONS; EACH SOIL TYPE WOULD BE A SUBJECT.

SOME THEMES DO NOT HAVE DIGITIZED DATA FOR ALL FOUR QUADS IN THE STUDY AREA.

ENVIRONMENTAL AND ADMINISTRATIVE THEMES USED TO ASSESS THE ARCHEOLOGICAL INVENTORY DATA:

ENVIRONMENTAL

- DRAINAGES
- STREAMS
- GEOLOGIC SURFICIAL PROCESS UNITS
- SURFACE GEOLOGY
- SOILS
- *ELEVATION
- *SLOPE
- *ASPECT

ADMINISTRATIVE

- WILDERNESS STUDY AREAS (WSA)
- LINEAR DEVELOPMENT IN WSA
- ROAD NETWORKS
- RANGE ALLOTMENTS
- OIL AND GAS LEASES
- PREFERENCE RIGHT LEASE APPLICATIONS FOR COAL
- INDUSTRY EXPRESSIONS OF INTEREST IN COAL LEASING
- PROPOSED AREAS OF CRITICAL ENVIRONMENTAL CONCERN
- LAND STATUS (OWNERSHIP)

* ELEVATION WAS DERIVED FROM DIGITAL ELEVATION MODELS (DEMS). SLOPE AND ASPECT WERE DERIVED FROM ELEVATION MAPS USING SLOPE AND ASPECT COMMANDS IN MAPS, RESPECTIVELY.

Figure 1

Data Themes Used for Analysis

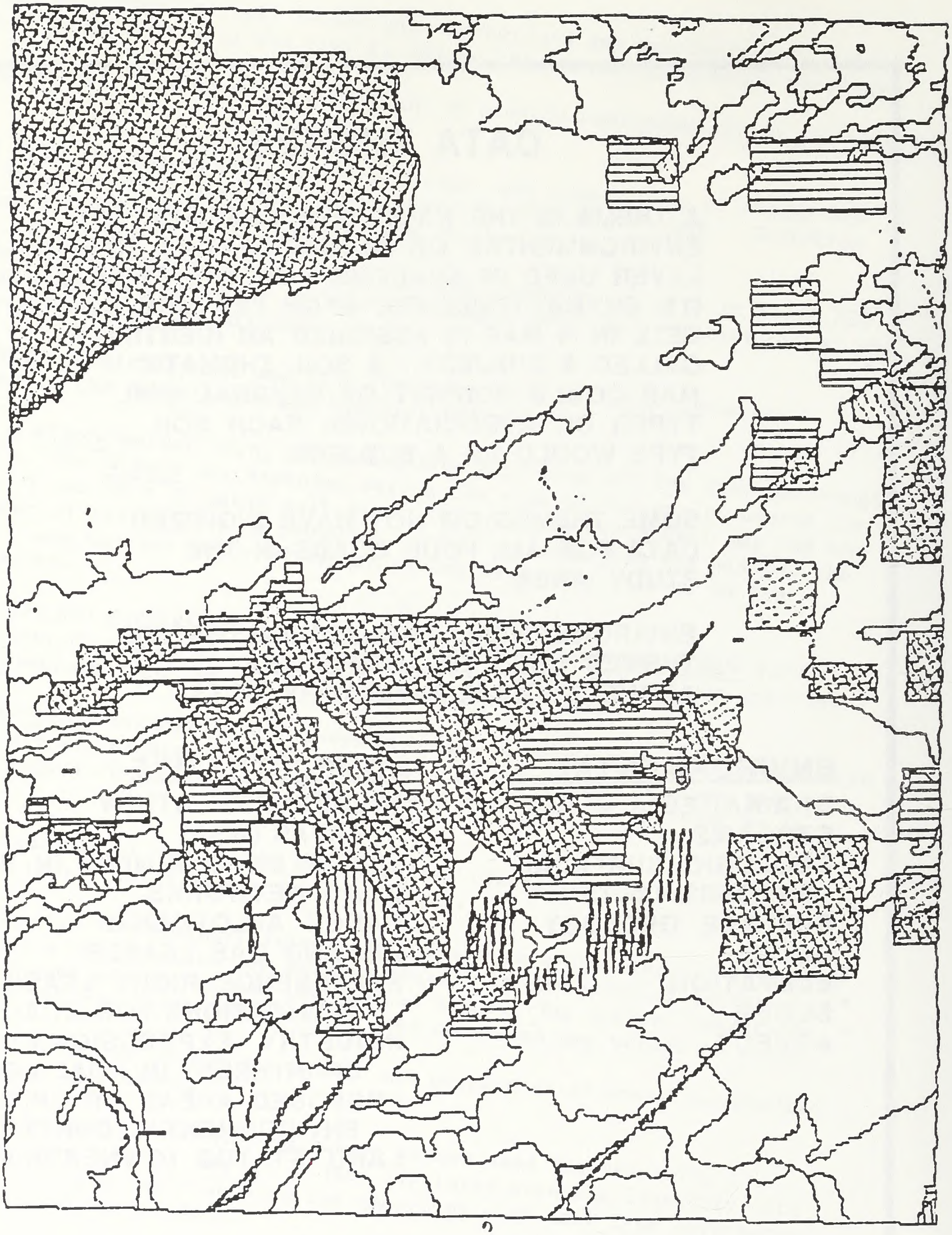


Figure 2

Soils Data Overlayed With Inventory Data
(Shaded areas show intersection of 13
soil types with inventory data)

Table 1

Area Table of Soils Data Overlayed With Inventory Data

```
? AREA SURVSOILC

  26 SUBJECTS IN AREA SUMMARY FOR MAP SURVSOILC           06/05/86
  ID        VALUE        AREA FREQUENCY     %  SUBJECT

   1    1001.0000     9670.17   43482.0  6.27
   2    1002.0000     2541.97   11430.0  1.65
   3    1003.0000        2.67      12.0   .00
   4    1004.0000      819.97    3687.0   .53
   5    1005.0000      831.31    3738.0   .54
   6    1006.0000         .00        .0   .00
   7    1007.0000        3.11      14.0   .00
   8    1008.0000     5428.88   24411.0  3.52
   9    1009.0000        1.56       7.0   .00
  10    1010.0000       75.17     338.0   .05
  11    1011.0000    12326.68   55427.0  7.99
  12    1012.0000    15228.71   68476.0  9.88
  13    1013.0000         .00        .0   .00
  14       1.0000    45333.18  203841.0 29.40
  15       2.0000    11142.20   50101.0  7.23
  16       3.0000      575.34    2587.0   .37
  17       4.0000     6040.69   27162.0  3.92
  18       5.0000     7552.97   33962.0  4.90
  19       6.0000       48.04     216.0   .03
  20       7.0000        8.67      39.0   .01
  21       8.0000     4317.35   19413.0  2.80
  22       9.0000      744.80    3349.0   .48
  23      10.0000     6344.25   28527.0  4.11
  24      11.0000    23289.95  104723.0 15.10
  25      12.0000     1743.13    7838.0  1.13
  26      13.0000      122.09     549.0   .08
-----------------------------------------------
TOTAL ACRES           154192.7  693329.0 91.42  :      14471.5 ACRES BACKGROUND:
```

Note: Value column is the cell value of each soil type (subject) intersected (1001-1013) and non-intersected (1-13) with inventory data.

Area column is the acreage associated with each intersected and non-intersected value.

Frequency column is the number of cells associated with each value.

% column is the area percentage of each subject occuring in the study area.

The remainder of this paper focuses on the use of MOSS/MAPS for aiding in the identification of existing or potential cultural resource and land use conflict areas. The aim was to select all Archaic sites and associated attributes for each site that are recorded for the project area and overlay that data with each administrative theme. The following steps show the procedures that were performed for this aspect of the analysis.

1. The archaeological site and associated attribute information is kept on the Archaeological Resource Management System (ARMS), a data base containing only alphanumeric data. The data base is maintained and updated regularly by the Laboratory of Anthropology, an agency of the New Mexico State Government. This data base management system is used by the state for data retrieval using an IBM mainframe.

2. The site data were loaded on tape at the Laboratory of Anthropology and then sent to the Data General minicomputer at the BLM New Mexico State Office. A digital planimeter was used by the Laboratory to derive UTM coordinates for plotting sites on a master map from which the data was encoded to ARMS.

3. A special conversion program was developed at the BLM Service Center to convert the data from the IBM format to MOSS format. At the same time, any site which did not have good or excellent locational accuracy, as coded on the data file, was omitted. The graphic data base is stored on 1:100,000-scale maps that are subdivided into four columns, each being two 7 1/2- minute quadrangles wide. The division of the 1:100,000-scale map is required due to the limitations of the special conversion program which accepts only 2,750 unique subjects (sites) in any one run.

4. The file containing the point data for the sites is then linked with the associated attribute files from the ARMS data base.

5. The site and attribute data was copied onto tape and sent to the BLM Service Center for manipulation on MOSS.

6. GENERATE a WINDOW border using UTM coordinate pair data for the four-quadrangle study area. The WINDOW was expanded beyond the edge of the map to create even multiples of the 30 x 30 meter cell size. In this way, each cell map had the exact number of cells, with no rounding error. By enlarging the WINDOW, the edge of the map did not obscure the border when viewed on the terminal screen.

7. LPOVER the portion of the 1:100,000-scale map containing the site data with the WINDOW border. The resulting map includes only the archaeological site data for the four-quadrangle study area (603 sites).

8. BSEARCH the map with 603 sites to select all sites and occupations (components) dating to the Archaic period with their multiple attributes. This map had a total of 137 Archaic sites with multiple attributes.

9. REPORT to generate a tabular listing of the multiple attribute data base for the map with the 137 Archaic sites.

10. PLOT the map of 137 Archaic sites on the terminal screen to view the distribution of the sites.

11. NUMBER the map of 137 Archaic sites to display the ID number of the sites on the map.

12. EDITATT using the cursor option to interactively edit the contents of the map's multiple attribute file. The objective is to place all of the Archaic period attribute information into the first of the three nested temporal matrices (components) of the ARMS file. This procedure was performed in order to retrieve attribute information from only one set of nested attribute matrices, rather than from all three. Most of the Archaic sites had been encoded in the first nested matrix for the first component.

13. The remaining attribute "keys" were then deleted with UTILITY using the "attribute" and "delete" options. This step was performed to reduce the processing time when using BSEARCH to search the multiple attribute file.

14. BSEARCH the 137 Archaic site map nine times to obtain a separate map for each of the nine site size ranges encoded in the ARMS file.

15. BUFFER each of the nine site size maps using the radius calculated for the value at the upper end of the size range (size ranges are provided in ARMS file). This procedure will give a conservative estimate of the area to be BUFFERED for the sites occurring in that size category. The "resolve overlap" option for the BUFFER command was not used because inaccurate area figures were being calculated because of algorithm problems that existed for this particular version of MOSS. As a result, each site retained its own BUFFERED area. Note: Sixteen sites were "lost" after RASTERIZING the BUFFERED data because more than one of the polygons of the smaller size ranges fell within a single 30 x 30 meter cell. This resulted in the loss of one or more cell frequencies for that particular site size map. This problem was experienced for some or all of the sites having 25m^2, 100m^2, and 500m^2 areas. A larger cell size would have resulted in greater site "losses." The problem was resolved by SELECTING by item number only those sites that did not receive a cell frequency and rebuffering them using the upper end of the range of site size category 4, which was 1,000m^2. No sites were lost at this area size when the BUFFERED sites were later RASTERIZED. Although the BUFFERED Archaic sites may not have highly accurate areas calculated, they provide vividness for purposes of graphic display.

16. MERGE all BUFFERED and rebuffered site maps to produce a map containing the BUFFERED 137 Archaic sites that represent rough area approximations for each of the sites.

17. RASTERIZE the BUFFERED 137 Archaic site map to convert to cell format with background and non-background values. A 30 x 30 meter cell size was used to obtain a very high resolution and to minimize the loss of sites in the event more than one polygon fell within a cell. After rebuffering only one polygon (site) was lost. Note: Administrative themes were previously RASTERIZED to assess the archaeological inventory data.

18. INTERSECT each of the RASTERIZED administrative data themes with the RASTERIZED BUFFERED 137 Archaic site map to create a new discrete map showing logical intersection of sites with the subjects of each administrative theme. Some subject name labels were modified with the LABEL command using the subject option.

19. PLOT and SHADE the INTERSECTED map on the terminal screen to visually inspect the areas of each administrative theme where proposed or existing development is conflicting with existing Archaic sites in the area.

20. AREA the INTERSECTED map to obtain the approximate acreage of Archaic sites that coincide with areas of planned development or conservation.

Figure 3 shows the Preference Right Lease Applications (PRLA) for coal overlayed with the Archaic site data. The PRLA map was then plotted on the map showing intersection. (Note: The southwest quadrangle for PRLA data was unavailable at the time of analysis.) Table 2 shows a portion of the area table of the PRLA data overlayed with the Archaic site data.

SUMMARY AND CONCLUSIONS

The federal archaeologist is often involved with analyzing archaeological data to meet planning and operational management requirements, which include the preparation of RMPs, EARs, and EISs. In order to accomplish these work requirements, the archaeological site inventory data must be assessed, and areas of cultural resource and land use conflict identified. This paper has presented some specific MOSS/MAPS commands and procedures that will aid federal archaeologists in meeting their analysis needs.

Benefits of using MOSS/MAPS for cultural resource management include the following:

1. Increased speed for performing spatial analysis for meeting work requirement needs;

2. Accurate area measurements generated for inventoried and land use conflict areas; and

3. Performance of archaeological site and environmental location analysis for purposes of site density projection.

Difficulties of using MOSS/MAPS for cultural resource management include the following:

1. Some archaeological sites were "lost" after converting to cell format.

2. Very small cell sizes, e.g., 30 x 30 meters, require more disk space and greater processing time than larger cell sizes.

3. Advanced statistical capabilities are lacking to perform correlative and inferential analyses.

REFERENCES

U.S. Department of the Interior, Bureau of Land Management, 1978, 8100-Cultural Resource Management (Manual).

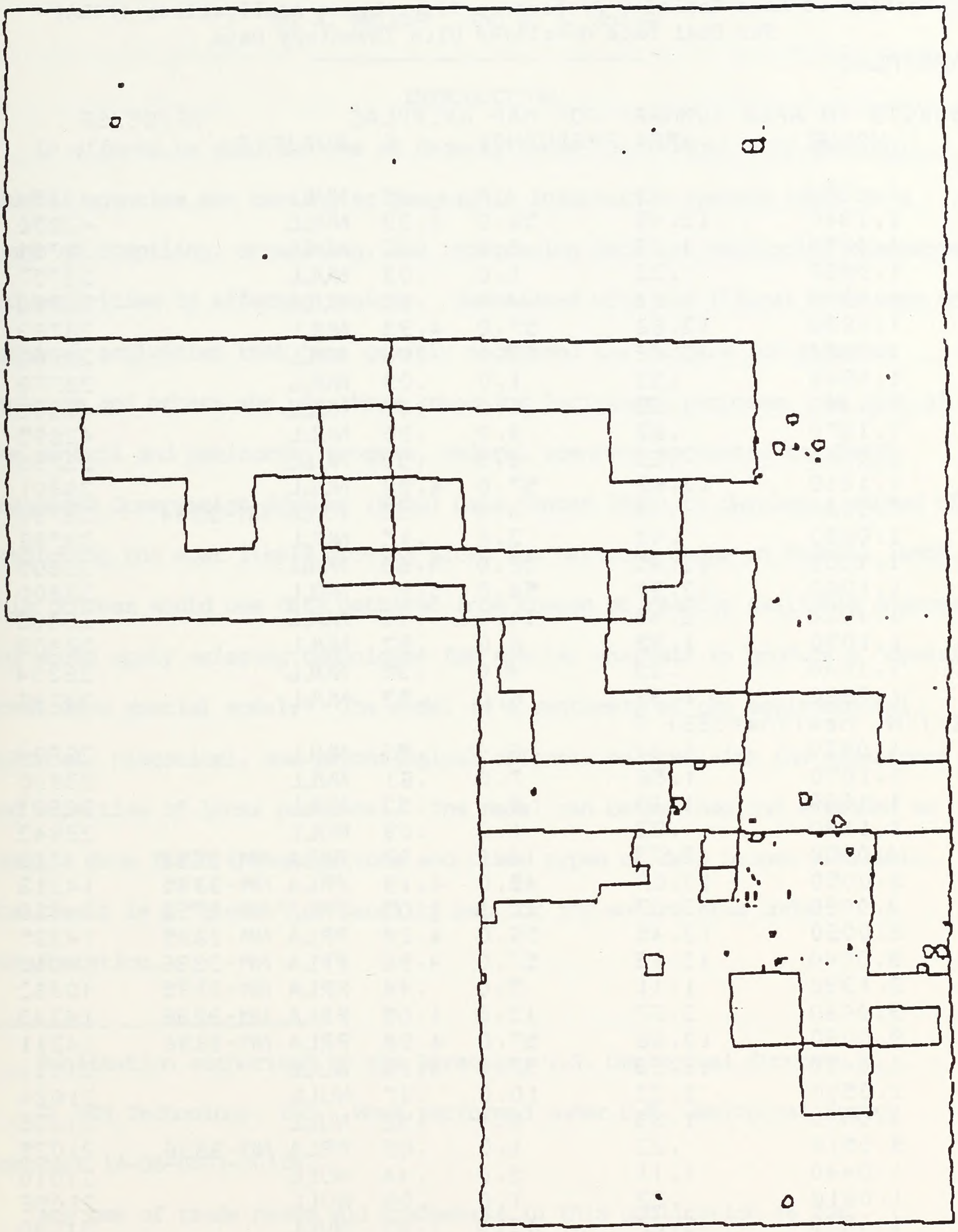


Figure 3

Preference Right Lease Applications (PRLA) for Coal Data Overlayed with Inventory Data

Table 2

Portion of Area Table of Preference Right Lease Applications (PRLA)
For Coal Data Overlayed With Inventory Data

```
? AREA ARCPRLAC

  73 SUBJECTS IN AREA SUMMARY FOR MAP ARCPRLAC          06/05/86
  ID        VALUE          AREA FREQUENCY       %  SUBJECT

    1        1.1350          .89        4.0   .35  NULL                 42954
    2        1.1340        12.45       56.0  4.89  NULL                 42950
    3        1.0950         1.33        6.0   .52  NULL                 28791
    4        1.0900          .22        1.0   .09  NULL                 28757
    5        1.0910          .89        4.0   .35  NULL                 28758
    6        1.0930        12.68       57.0  4.98  NULL                 28763
    7        1.0920        12.68       57.0  4.98  NULL                 28762
    8        1.0940          .22        1.0   .09  NULL                 28773
    9        1.1360          .22        1.0   .09  NULL                 42893
   10        1.1370          .89        4.0   .35  NULL                 42895
   11        1.0960          .22        1.0   .09  NULL                 28790
   12        1.1010        12.68       57.0  4.98  NULL                 28801
   13        7.0960          .89        4.0   .35  PRLA NM-3834         28796
   14        1.0980          .44        2.0   .17  NULL                 28796
   15        1.1050        12.45       56.0  4.89  NULL                 28805
   16        1.1000        12.90       58.0  5.07  NULL                 28800
   17        1.1020         2.45       11.0   .96  NULL                 28802
   18        1.1030         1.33        6.0   .52  NULL                 28803
   19        1.1040          .89        4.0   .35  NULL                 28804
   20        1.0990         1.33        6.0   .52  NULL                 28793
CONTINUE(Y/N, newline=YES) ?
   21        1.0970         1.33        6.0   .52  NULL                 28794
   22        1.1070         1.56        7.0   .61  NULL                 28930
   23        1.1080         1.33        6.0   .52  NULL                 28931
   24        1.1130          .22        1.0   .09  NULL                 28942
   25        4.0050         2.22       10.0   .87  PRLA NM-3753         14213
   26        8.0050        10.67       48.0  4.19  PRLA NM-3335         14213
   27        3.0090         2.67       12.0  1.05  PRLA NM-3752         14926
   28        8.0050        12.45       56.0  4.89  PRLA NM-3335         14235
   29        9.0040        12.68       57.0  4.98  PRLA NM-3836         14212
   30        8.1330         1.11        5.0   .44  PRLA NM-3335         40322
   31        9.0060         2.67       12.0  1.05  PRLA NM-3836         14243
   32        9.0030        12.68       57.0  4.98  PRLA NM-3336         14211
   33        1.0450        12.68       57.0  4.98  NULL                 21011
   34        1.0500         2.22       10.0   .87  NULL                 21024
   35        1.0510         1.33        6.0   .52  NULL                 21025
   36        9.0510          .22        1.0   .09  PRLA NM-3336         21025
   37        1.0440         1.11        5.0   .44  NULL                 21010
   38        1.0610          .22        1.0   .09  NULL                 21058
   39        1.0520         2.67       12.0  1.05  NULL                 21030
   40        1.0530          .22        1.0   .09  NULL                 21032
   41        1.0540         1.33        6.0   .52  NULL                 21033
   42        1.0600          .44        2.0   .17  NULL                 21053
   43        1.0470          .22        1.0   .09  NULL                 21020
```

Note: Columns are the same as noted in Table 1, except subjects are PRLAs and archaeological site numbers instead of soil types and inventory numbers.

MODELING NARCOTIC CROP-GROWING SITES WITH MOSS

F. A. Waltz[1], and E. A. Holm[1]

INTRODUCTION

In efforts to stop the use of Federal lands for illegal crop growing, Federal agencies are turning to geographic information systems (GIS) as a means of compiling, organizing, and integrating data for monitoring resources and activities in affected regions. Associated with the illegal practices are criminal activities that have greatly increased the dangers for resource managers and others who use these areas for legitimate purposes. As part of the control and monitoring program, Federal agencies requested the Earth Resources Observation Systems (EROS) Data Center (EDC) to develop a method of predicting the most likely growing sites for narcotic crops on Federal lands. This process would use data gathered from common or readily available sources and would apply existing techniques for spatial analysis to produce a "dynamic predictive spatial model." The model is a synthesis of the environmental, cultural, historical, and psychological criteria defined with the experience and expertise of local personnel. The model can be refined and extended as results from field investigations and other types of data become available. The result is a "growth" probability map for the entire area under consideration.

Publication authorized by the Director, U.S. Geological Survey.

[1] TGS Technology, Inc. Work performed under U.S. Geological Survey contract 14-08-0001-20129.

Any use of trade names and trademarks in this publication is for descriptive purposes only and does not constitute endorsement by the U.S. Geological Survey.

After 2 years of tests, a decision was made at EDC to implement the modeling procedure on a Data General microcomputer using a Department of the Interior (DOI) version of the Map Overlay and Statistical System/Map Analysis Package System (MOSS/MAPS). Such a process would then be available at agencies with similar systems that rely on this software for GIS activities. The methods for modeling are described in this paper; the current study with MOSS/MAPS is discussed as part of the implementation and in the results.

MODEL COMPONENTS

The model components include terrain characteristics, natural resources, and cultural features. Initial models for a given area may include historical data related to past growing patterns, and subsequent models may be evaluated and refined using results from current field surveys. Terrain characteristics were derived from US GeoData Digital Elevation Model (DEM) data based on the USGS 7.5-minute topographic quadrangle map series. Component categories for slope, aspect, and surface illumination were derived from the raster-formatted elevation data. Water resources were manually digitized from thematic maps, and rasterized. In the case of manmade water sources such as wells or stock ponds, aerial imagery can be used for verification and update. Dominant vegetation types and canopy density were manually interpreted from aerial imagery, and class maps were produced, digitized, and raster-formatted. These digitized resource categories were also maintained in vector form for updating purposes.

Cultural features include roads and dwelling, which were manually digitized from thematic maps that had been updated using aerial imagery. The cumulative mapping of the growing patterns from previous and current investigations may be treated in a similar manner.

Derivative categories for each of the criteria in the model were derived from the database using classification, proximity functions, and edge detection. The parameters for the model were generated by applying numerical weights to each category. These derivative categories, which are statistical estimators of each criterion, were combined to produce the final model.

THE MODEL

The basic form of the model is:

$$P = (p_1 + p_2 + p_3 + \ldots + pn)\ (l_1)\ (l_2)\ \ldots\ (l_m).$$

where,

P is the probability of occurrence,

p_n is the probability for criterion n, and

l_m is a limiting factor for criterion m.

In this form, the p's are additive and, thus, are contributing but not constraining components, whereas the l's are multiplicative and are used as constraining factors by imposing limiting conditions on the combined model, not just the associated criteria. In other words, the model will only be applicable in areas where the limiting criteria are nonzero. This effectively reduces its complexity and the area that needs to be monitored, thus increasing the efficiency of the model.

The probabilities (numerical weightings) are based on considerations of growing conditions and psychological inferences from the knowledge and experience accumulated by local personnel. Terrain factors (elevation, slope, aspect, and illumination) are weighted according to their effects on growing requirements. Resource (water, soils, vegetation) and cultural (roads, dwellings) features are important in indicating proximity to growing sites and the perceived accessibility to them. A likely "zone of influence" can be circumscribed around each resource. For several criteria, there may be a number of concentric zones of different weights around each resource, because the use potential (or probability) changes with distance. Historical finds and current observations can be used to check and refine the model.

Categories may be combined into probability submodels when related criteria are involved. This allows the model to be examined at intermediate stages where it is easier to study its behavior and correct or modify parameters. The same holds true when it is being refined from results of field investigations. The submodels are then combined to produce the final composite model. Models for the current study are based on a set of five submodels: terrain, water sources, vegetation, dwellings, and roads.

Implementation

These modeling procedures have been developed and implemented on several different systems at EDC. The database components used to test these systems were captured (digitized from thematic maps or extracted from other digital data) and registered on minicomputers. A prototype model was developed on a microcomputer-based image processing system and subsequent testing was done on a minicomputer to study the feasibility of a production procedure. The product generally used at the present time is a clear mylar overlay scaled to fit a standard 7.5-minute topographic map sheet. The overlay contains two or three color-coded probability classes that represent an areal percentage of the entire model covered by the highest probabilities. The classes indicate the primary areas to consider for investigation, based on the current model parameters.

In the current pursuit of a similar modeling process on a MOSS workstation, EDC employs a Data General Model 10/SP desktop microcomputer. This 16-bit computer has floating-point processing support, 1.7-Mb random access memory, and 140-Mb disk storage. The installed MOSS/MAPS software package is a version used by various agencies in the Department of the Interior. MOSS/MAPS is nonproprietary, and can therefore vary in content and performance between installations. The results obtained in this project are valid for the September 1985 release as installed on the Data General Model 10/SP at EDC.

Data compiled for a previous test area were chosen as references for evaluating results. To build the database, the original digitized data categories were converted to MOSS import format using software developed at EDC. EDC supports reformatted and restructuring of files between many systems. Elevation data in UTM projection were converted to 2-byte raster form from the DEM product run-length encoded format. The surface illumination data, which is derived from elevation, cannot be generated in MAPS, and was made on a minicomputer with a function that estimates the slope at each point and calculates the angle between the local slope and a specified illuminating point source. Slope and aspect data (also derived from the DEM data) were generated in MAPS with the appropriate functions. All of the data layers were collected on a VAX 11/780 in preparation for transfer to the DG.

The DG-10/SP has no magnetic tape format compatible with the VAX for exchanging data. Also, transfer of data by direct communications link has been unreliable, given large data sets which are frequently several hundred kilobytes. Consequently, the data were moved to the DG-10/SP on floppy diskettes.

The available DG-10/SP software includes an MS-DOS operating system emulator which runs under the main DG operating system, AOS. This emulator and the associated utilities can use hard-disk and floppy-disk resources and provided a path for moving the data from the VAX. The data were first transferred from the VAX to a microcomputer using the KERMIT communications program. Data files were then loaded onto floppy disks in MS-DOS format. On the DG-10/SP, the files in MS-DOS format were transferred through an MS-DOS utility and converted to AOS file formats for installation in MOSS or MAPS. Because of a mismatch in the utility versions, it was not possible to reverse the process and transfer these or other large data sets back to the VAX. This prevented moving files to the VAX for output product generation.

Vector data are installed in MOSS from an import format in which the data are in ASCII form. The ADD function in MOSS converts this form to a binary data format, which MOSS uses for all processing. Raster data must be in binary format since there is no conversion function. The data are installed using the IMPORT function in MAPS, which builds header information for the data. The ADD function requires parameter information about the map projection for each category, which may not be available. The precision required depends upon whether projection changes or combination with data from other sources are anticipated. Both of these processes require very precise projection characteristics. Many MAPS functions are sensitive to the dimensions of the map grid, the size and area of the grid cells, and the bounding coordinates. In fact, for this installation's MAPS, the internal precision often exceeds the precision required (or possible) when entering the characteristics. The procedure for entering the elevation and surface illumination data required several repetitions before an acceptable compromise was reached between the grid size and the boundary. Vector-to-raster conversions produced small but critical variations in these parameters, which inhibited integration of different data categories.

Because of functional limitations of this MOSS version and the dependency of the modeling process on raster-format topographic data, it was decided to pursue the major portion of the project by using MAPS. In order to use the vector data in this MAPS version, they were rasterized to a grid to create a cell map of the data. Vector data categories were rasterized to a 30-m cell size using the POLYCELL function in MOSS. The cell values were assigned according to the sequential listing of the subjects in the vector category. Assigning values by subject means the first listed subject is assigned a value of 1, the next subject, a value of 2, and so on. In POLYCELL, the cell size is not determined by specifying the cell dimensions (x,y), but by entering the aspect ratio of a cell (heighth/width) and the area the cell represents in acres. Since the data were converted to match the raster grid of the elevation data, the acreage fraction was worked out to five significant digits. Although this was more precise than the value reported back by the system, it was not an exact match for the elevation cell acreage, nor did the subsequently computed cell dimensions match. This was discovered later, during attempts to combine the categories arithmetically. This version of MOSS does not provide means of checking these values, and the alternative was to find them in the files' records, to examine, and to correct them in binary form. The raster categories were created as discrete data types based on the thematic nature of the vector data. This posed restrictions during subsequent process steps because of data-type constraints associated with various functions (the same kinds of restrictions apply to "continuous" data for a different set). Numeric class codes were used as subject descriptors in the vector categories. To simplify processing, the rasterized data were renumbered to the original class codes. This step is not necessary if an accurate cross-reference list for cell values, subject numbers, and descriptors is maintained.

For criteria where distance effects were analyzed, buffer zones were constructed as a measure of proximity to significant features. The ZONE command was used to generate concentric zones approximately 1-cell wide around the target values in each category. The number of zones ranged from 1 to 16, incorporating potential sites up to ½ kilometer from the target. The intervals were numbered consecutively starting with 2 for the innermost ring, with the targets set to 1. Buffer zones constructed for point data included dwellings, springs, and small ponds, using distances up to 200 m from the elements. Buffer zones were constructed for line data out to approximately 500 m for all streams, and for three different classes of roads. Similar zones were generated around lake polygons. A layer identifying all of the edges between forested and open areas was created by outlining all polygons in the forest canopy data with a zone one cell (30 m) wide.

Estimation categories for each of the model criteria were created by numerically weighting the elements in each of the criterion categories to produce the parameters for the model. This version of MAPS has two functions to assign the weights, EXTRACT and RENUMBER. EXTRACT was chosen because it produces a discrete data set in which all selected features are reassigned new values and the rest are set to zero. The values assigned to differing elements reflect their relative importance within that category and the range of values assigned to each category reflects the relative importance between categories. Weightings applied to buffer zones around features were assigned as an inverse function of distance from the feature. Categories for the constraining conditions were generated by setting all features for which the model did not apply to zero, and all others, to one. For example, a site cannot be located in the middle of a stream, therefore the "mask" categories for streams contains zeroes at all stream locations, and contains ones for the remaining background.

The process of moving all of the data into this version of MAPS is irreversible since the procedures for raster-to-vector conversion are not available.

Problems were encountered in registering the various data categories. Whereas the digitized thematic data are projected to match 7.5-minute topographic maps, digital elevation data are provided in UTM projection. Since the final map must be in a form compatible (registered) to the standard quadrangle, projection conversion is required. This capability does not exist for raster data in these versions of MAPS and MOSS, and the model must therefore be processed through another system.

CONCLUSION

While the modeling procedure proved successful in field tests, its practical implementation under these versions of MOSS/MAPS was not proved. Although the results were not analyzed in detail, it is obvious that substantial modifications will have to be made to the current procedure. For example, more preprocessing work on other systems would be necessary, due to the lack of required facilities in these versions of MOSS and MAPS.

This version of MOSS was not a suitable environment for the modeling approach taken here, which depends heavily on continuous spatial variability and requires a high degree of data integration.

1. The model results are based upon an accumulation of numerical evidence using arithmetic operators. They are not based upon sets of binary conditions, which can be analyzed using logical or boolean operators. This version of MOSS cannot combine data categories arithmetically.
2. Several of the data categories require a series of concentric buffer zones around selected features. Constructing these buffers was very difficult and time consuming.
3. Constructing appropriate edge relationships for these data in this version of MOSS was extremely difficult.

MAPS has the facilities necessary for synthesizing the model with certain restrictions; unfortunately, the various facilities for output and georeferencing do not currently extend to this version. Examination of intermediate results, which is valuable in an iterative process such as this, is quite time consuming. This version of MAPS does have the tools to build the model, but restrictions on data types, grid selection, and sizing, add a substantial number of steps to the procedure, some of which cannot be accomplished within the confines of the system. It was found that in order to achieve acceptable results, the following criteria must be met prior to any data integration using MAPS:

1. All raster categories must be registered to a common base.
2. All raster data must be in the same map projection. Only vector data can be reprojected. If reprojection is necessary it must be done before rasterization. There is no functional raster-to-vector conversion.
3. All raster data categories must have exactly the same cell size and cell area (down to the computer's last binary digit).
4. All raster data categories must have exactly the same number of rows and columns.

Producing the model in this version of MAPS was a difficult task, because of constraints on the integration, aggregation, and merging of data of different types and further restrictions related to cell grid variations in size and density. To produce the final model, it was necessary to commit a series of extrinsic file manipulations.

The effects of these restrictions must be planned when using these systems.

REFERENCES

Waltz, F. A., and Moore, D. G., 1986, Predictive modeling of narcotic crop growth: U.S. Geological Survey Open-File Report No. 86-007.

Lee, J., Reed, C., Frosh, R., Sullivan, L., and D'Erchia, F., 1985, MOSS user's manual (version 85.01): Fish and Wildlife Service, U.S. Department of the Interior, 1985.

MAP OVERLAY AND STATISTICAL SYSTEM (MOSS)
TERRAIN DATA HANDLING CAPABILITY

Randy A. McKinley
TGS Technology, Inc.
Bureau of Land Management Operations
P.O. Box 28J, Station #16
Lakewood, CO 80228

ABSTRACT

Current capabilities of the MOSS Geographic Information System (GIS) for the manipulation of digital terrain information are discussed and explained. Emphasis on data availability and cost, data entry, data quality, practical limitations, and data manipulation (i.e., slope and aspect calculation) provides MOSS users with a basis for making terrain database development decisions. Examples of existing and potential Bureau of Land Management (BLM) applications for digital terrain data, within the context of a natural resource management GIS, are provided.

INTRODUCTION

The BLM manages approximately 350 million acres of range and timberland in the United States. In order to assist field personnel in the management of these land resources, the BLM uses a variety of information types to develop digital databases within a Geographic Information System (GIS). Digital elevation data have routinely been used by the BLM to provide terrain related parameters such as elevation , slope, and aspect for inclusion in geographic databases (McKinley, 1985).

The BLM has conducted numerous large-scale GIS projects. These projects were accomplished utilizing the Map Overlay and Statistical System (MOSS) and the Interactive Digital Image Manipulation System (IDIMS) as support in data manipulation. Within the framework of many of these projects, digital terrain data provided vital data layer elements in the GIS. Extensive experience relating to the utilization of digital terrain data in varying formats and scales has been gained by the BLM Service Center (SC) staff. Based upon this experience, an explanation of current MOSS capabilities relating to the manipulation of digital terrain data is provided. Specific information related to terrain data availability, cost, data entry procedures, data quality, practical limitations, and general terrain data manipulation functions within MOSS will provide MOSS users with a basis for making terrain database development decisions.

TERRAIN DATA AVAILABILITY

The U.S. Geological Survey (USGS) distributes digital cartographic and geographic data as part of the National Mapping Program (Elassal 1983). Three types of digital terrain data, all distributed by USGS, apply to BLM and other MOSS user groups primarily concerned with natural resource management.

USGS Digital Elevation Models (DEMs)

Two digital elevation data products are distributed in the standard DEM tape format: 1) DEMs produced by USGS that correspond in coverage to standard 1:24,000-scale, 7.5- x 7.5-minute quadrangles, commonly referred to as 7.5-minute DEM data, and 2) DEMs originally produced by the Defense Mapping Agency (DMA) and later modified by USGS, which correspond in coverage to 1 x 1 degree blocks (one half of standard 1:250,000-scale, 1 x 2 degree quadrangles), commonly referred to as 1:250,000-scale, DEM data (or Arc/Second Data). The 7.5-minute DEM data files and the 1:250,000 -scale DEM data files are identical in logical data structure but differ in sampling interval, geographic reference system, areas covered, and accuracy of data (Elassal 1983). USGS 1:250,000-scale DEM data are available for most of the United States while 7.5-minute DEM data are available for only selected quadrangles. For a fee ($500 to $1,000 depending on priority), USGS will expedite the creation of a desired 7.5-minute DEM.

The availability of 7.5-minute DEM data may improve substantially due to a recent agreement signed by the Forest Service and the USGS (USGS 1986). The Forest Service is currently generating digital elevation data for about 900 quadrangles per year and anticipates a total requirement of 10,500, 7.5-minute quadrangles to support emerging GIS applications and to drive offline orthophoto printers. As a result of the agreement, the two agencies will review the potential for digital elevation data exchange (USGS,1986).

DMA Digital Terrain Tapes (DTTs)

The USGS also distributes DMA 1:250,000-scale terrain/planar digital data as digital terrain tapes (DTTs). These data are distributed as produced by the DMA, and do not conform to standard DEM tape format. As with the 1:250,000-scale DEM data, DMA 1:250,000 data provide coverage for one half of a standard 1:250,000-scale quadrangle. The DTT database was completed for the conterminous United States and Hawaii in the late 1970s (Elassal 1983). Since that time, 1:250,000 DEMs have nearly been completed for the same area and most of Alaska. Due to more rigorous checks for accuracy and consistency, the 1:250,000 DEMs are generally considered as a higher quality source for elevation data than the DMA DTTs. However, both data types should be considered as acceptable sources of elevation data.

The USGS, through the National Cartographic Information Center (NCIC), provides various indexes for these data. However, they may be over 1 year old and, therefore not accurately reflect all available data. Current prices (1986) for these data are as follows: (1) 7.5-minute DEM, $100.00; (2) 1:250,000 DEM, $ 75.00; and (3) 1:250,000 DTT, $ 75.00. Requests for information (availability of data for specific quadrangles) and orders for these data should be directed to NCIC.

Historically, the BLM has used all three types of digital terrain information distributed by USGS. DMA 1:250,000 DTTs and USGS 1:250,000 DEMs have been used to develop relatively coarse elevation information over broad areas (1 x 1 degree), while USGS 7.5-minute DEMs have been used to provide higher resolution terrain information (30 meters), more suitable for presentation at a scale of 1:24,000 or smaller.

Terrain data distributed by the National Geophysical Data Center and other sources are not considered in this report. Data with extremely coarse resolution, such as the NOAA 5 minute mean elevation data for parts of the northern hemisphere and Europe, are generally considered to have few applications in the BLM. However, NOAA 30-second point elevation data, which have also been excluded from this report, have been extensively used by BLM in the fire fuels mapping effort for the western United States and various other broad-scale (1:250,000-scale or smaller), GIS mapping projects. The NOAA 30 second elevation data are available to BLM personnel at the SC, in a MOSS compatible format, for the western U.S. These data have been registered to appropriate UTM zones with a cell size of 1000 meters. More information on the utility of the 30 second data, in the context of BLM applications, is available at the SC (D-155).

TERRAIN DATA ACCURACY

DEM Accuracy

The 7.5-minute DEM data are produced from map contour overlays that have been digitized or from automated or manual scanning of photographs usually taken at an average height of 40,000 feet (1:80,000-scale). The data are processed to produce a DEM with a 30-meter, horizontal sampling interval (Elassal 1983). The accuracy of 7.5-minute DEMs depends on the data source (either aerial photography or contours on 7.5-minute USGS topographic maps). Vertical accuracy of the 7.5-minute DEMs derived from aerial photographs depends on the original resolution and contrast of the source photographs, as well as the presence of natural or man-made features and the abundance of survey control for constraining the stereomodels (Elassal 1983). The vertical accuracy of 7.5-minute DEMs derived from contours is consistent with the accuracy of the source map contours. All 7.5-minute DEMs distributed by USGS are classified into two vertical accuracy categories: those possessing less than 7 meter, vertical root mean square error (RMSE) and those possessing 7 to 15 meter, vertical RMSE (Hooper 1985). No official horizontal RMSE value is available for 7.5-minute DEMs, although some USGS test data indicate that it is less than 10 feet. All 7.5-minute DEMs use a UTM projection with a cell/pixel size of 30 meters.

The 1:250,000-scale DEM data are produced by interpolating elevations at intervals of 3 arc-seconds from contours, ridgelines, and drains digitized from 1:250,000-scale topographic maps. Three seconds of arc represents approximately 90 meters in the north-south axis and a variable dimension (ranging from 90 meters at the equator to 60 meters at 50 degrees latitude) in the east-west axis due to convergence of the meridians (Elassal 1983). The accuracy of 1:250,000-scale DEMs is consistent with the accuracy of the contours (50 feet in flat terrain, 100 feet in moderate terrain, and 200 feet in steep terrain) on the 1:250,000-scale topographic maps used to produce the data. Therefore a 1:250,000 DEM with a 200 foot contour interval spacing could be considered to have a vertical accuracy of plus or minus 200 feet. These data were processed with a knowledge of adjoining map elevation information which decreased data errors associated with the interpolation of elevation values near map edges. DMA DTTs do not have this advantage. The 1:250,000 DEMs use a longitude/latitude projection, with a cell/pixel size of 3 seconds of arc (not planar). This means all data files have equal numbers of columns and rows with actual (ground measured) cell size dependent on latitude. For example, 1 x 1 degree data files in Alaska will have the same number of lines and columns as those in New Mexico, but the cell size in Alaska will be smaller than the cell size in New Mexico.

DTT Accuracy

DMA DTTs were originally produced as a by-product of three-dimensional relief maps. Production began in the early 1960s with a process that was capable of recording digital elevation data by tracing contour lines etched on metal plates. Digital traces of ridges and streams were added to the digital contour data and an interpolation algorithm was applied to produce a cartesian grid of elevation values (Elassal 1983). This process was later refined and modified to use an automated graphic digitizing system (AGDS), which digitizes stable base materials containing contour lines and ridge and stream traces, as depicted on 1:250,000-scale topographic maps. The data are then vectorized, tagged, and edited before applying an interpolation algorithm to produce the cartesian grid of elevation values at 0.01-inch intervals (Elassal 1983; Faintich 1984).

The accuracy of the DMA 1:250,000-scale DTTs are compatible with the stable-base 1:250,000-scale map sheets from which they were digitized. The DTTs and the 1:250,000 map sheets have not been completely tested for vertical accuracy (Elassal 1983). DMA DTTs use a UTM projection with a cell/pixel size of 63.5 meters (planar).

MOSS DATA ENTRY

Digital terrain data can be entered into MOSS (public domain version 85-09) with varying methodologies depending on the specific data type and format. A tested procedure exists to enter 7.5-minute DEM (30 meter) data directly into MOSS. A tested procedure to enter 1:250,000 DEM data directly into MOSS does not exist. However, the format of 1:250,000 DEM data tapes closely conforms to that of the 7.5-minute DEM tapes. Minor modifications could be made to existing MOSS software that would enable direct data entry into MOSS. DMA 1:250,000 DTTs cannot be directly entered into MOSS. The SC has some alternative procedures for reformating the 1:250,000 DEMs and DTTs into a MOSS compatible format.

DEM Data Entry

USGS 7.5-minute DEM standard format tapes can be read directly into MOSS. Briefly, the DEM tape file is read utilizing the Data General Advanced Operating System (AOS) COPY command. The MAPS IMPORT command (with the Format=DEM option) then reformats the DEM disk file to create a cell file. Experience at SC has shown that occasionally non-standard DEM tape formats may be encountered. Deviation from the standard format is generally due to a variation in the tape blocking factor or inconsistencies in data header record format. Variable blocking factors may be adjusted for by using the AOS COPY/IMTR= switch. The capability to read non-standard tapes with MOSS is limited, however, most non-standard data can be read utilizing the SC IDIMS system with the reformatted data then transferred to MOSS.

Procedures for the entry of 1:250,000 DEMs into MOSS have not been defined. Development and testing of this capability is currently in progress. An alternative for directly entering data into MAPS is to reformat the data in IDIMS, then transfer the data to MOSS. This process is similar to that for 1:250,000 DTTs.

DMA Data Entry

The capability of directly reading DMA data tapes does not exist in MOSS. However, DMA data can be read into the SC IDIMS system or possibly other raster processing systems at non-BLM locations. Once the DMA data are reorganized into an IDIMS image format, they can be transferred to tape (in IDIMS transfer format) and entered into MOSS by using the Data General AOS COPY command and the MAPS IMPORT command (with the IDIMS WORD optional parameter).

MOSS DATA PROCESSING

Given that the majority of distributed terrain products are inherently raster in format, the MOSS cell processing subsystem (MAPS) is the primary tool for manipulating digital terrain data. The command set provides the GIS user with a wide array of raster/cell processing capabilities, including the creation of slope, aspect, viewshed, and numerous other output maps. A brief discussion of some of these capabilities follows:

The SLOPE command accesses continuous elevation data (i.e., a 7.5-minute DEM cell map) and computes slope (in percentage of rise over run) to create a new continuous map.

The ASPECT command accesses continuous elevation data (i.e., a 7.5-minute DEM cell map) and computes azimuthal aspect, or direction of surface slope, to create a new continuous map.

The CONTOUR command generates a line drawing of a continuous map (i.e., a 7.5-minute DEM cell map) by connecting those cells with equal values that fall on a specified elevation interval.

The EXTRACT command is a data reclassification command that creates a new discrete map (i.e. slope class map) by assigning new values to the cell values of an existing discrete or continuous map (i.e., a continuous slope map generated by the SLOPE command).

The above functions represent a small fraction of the possible cell processing commands, or combinations of commands, that can be used to complete an analysis effort. Users should consult current documentation when considering raster processing within MOSS.

GIS APPLICATIONS

Digital terrain data are widely used for a variety of applications. DEMs and DTTs have been utilized for engineering planning and design efforts, such as volume measurements, route location analysis, and trafficability. Hydrologic applications, such as river basin, stream network, and surface depression or lake detection, and forestry applications, such as harvest suitability determinations have also been demonstrated (Chan 1985; Jensen 1984; Wong 1983).

Within the BLM, the accuracy of land cover maps developed from remotely sensed data (i.e., Landsat MSS, NOAA-AVHRR) have been improved by using elevation, slope, and aspect stratification prior to image clustering and classification, and during post-classification refinement (McKinley 1985; Johnson, 1981). Hundreds of slope and aspect maps, at a scale of 1:24,000, have been created by the processing of 7.5-minute DEM files. Digital terrain data, similar to 1:250,000 DEM files, have been used to develop statewide viewshed maps depicting radio tower shadowing problems in Utah. In addition, 7.5-minute DEM data in conjunction with water source information has enabled the BLM to model expected grazing pressure (EGP) for the Pinedale and Kemmerer resource areas in Wyoming (Foster 1986).

Future applications for digital terrain data within the BLM should be extensive. Perspective simulations (Dubayah 1986), the customizing of digital cartographic data presentations, and increased capabilities for modeling numerous natural resource parameters should provide resource managers with powerful analysis tools.

PRACTICAL CONSIDERATIONS

With increased use of various sources of digital terrain data, an analyst will come to recognize many re-occurring problems associated with the manipulation of those data. Below is a summary of a few of the major problems an analyst can expect to encounter when developing a terrain database. These considerations primarily apply to 7.5-minute DEM data since they are currently the most heavily used data source within BLM.

1. A fraction of 7.5-minute DEM files/tapes will not conform to the USGS standard format as currently described. Data files have been observed to possess a) varying header record formats, b) varying blocking factors, c) binary data rather than ASCII, and d) bad data lines or points. It should be noted that most 7.5 DEM files do conform to expected standards and should not present any problems for the data analyst. If difficulty reading standard DEM files is encountered notify NCIC to rectify the problem.

2. DEM files are generated with varying processes (i.e., auto-correlation, manual correlation). Data generated by manual correlation techniques will tend to exhibit less noise than auto-correlated data. This phenomenon may not be significant unless two extremely varying quadrangles are merged and displayed. To adjust the data values to a more equivalent state, a slight smoothing of the auto-correlated data can be conducted. A moving window (i.e., 3 x 3 cells) smoothing algorithm currently does not exist in MOSS. Data files may be smoothed in IDIMS and transferred to MOSS as an alternative.

3. When merging multiple DEM files into one map, the potential for generating zero or fill values along the quadrangle neat lines is high, and to be expected. To avoid future problems with the terrain data set zeros within the merged map should be located and modified to an adjacent cell value. This process of zero replacement can be conducted in MOSS through a sequence of commands requiring significant analyst effort as well as system disc space, depending on the number of quadrangles within the merged data set. For merged data sets with a large number of quadrangles (10 or more) and substantial zero value problems, BLM

data analysts should consider utilizing IDIMS for fixing the zero problems or for building the merged data set initially.

4. Examination of multiple DEM files has shown that elevation values may vary significantly in water bodies. This problem may manifest itself when a map is generated showing classes of slope (i.e., 0 to 10%, 11 to 20%, etc.) and individual water bodies exhibit more than one slope class. This error in data is to be expected. To eliminate the data problem, one must interactively edit the data by using a) MOSS or IDIMS or b) by generating a no slope mask by digitizing water bodies and overriding the original DEM elevation/slope values. USGS is in the process of correcting this problem during the creation of future DEM files.

5. Examination of multiple DEM files has shown that noise or elevation data errors will be evident within the majority of DEM files (Keating 1984). This problem can most easily be observed in areas of known flat terrain (0 to 2% slope), although the errors are not limited to those slopes. These errors are difficult if not impossible to eliminate. It is generally considered a problem an analyst will have to accept. The errors can be minimized by avoiding excessively detailed (more detail than the application requires) elevation class, slope class, and aspect class output products. For example slope class maps with breakdowns in slope of 0 to 3%, 4 to 6%, 7 to 10%, etc. will appear to exhibit significantly more erroneous data than a slope class map with a more inclusive slope class breakdown (i.e., 0 to 10%, 11 to 20%, etc.), especially in areas of flat terrain and water bodies.

6. All 7.5-minute DEM files will have a cell size of 30 meters and are registered to their associated UTM zones. Modifying the original cell size to be compatible with a 50-meter MOSS database requires resampling the original DEM cell data. There is an effort to develop this resampling capability in MOSS. Currently cell data can be resampled in IDIMS with data then transferred to MOSS.

7. The MOSS SLOPE command may generate erroneous slope values for those pixels near the edge of a DEM or DTT elevation map. This is caused by the inclusion of non-map data (fill data outside a map but inside the data minimum bounding rectangle (MBR)) in the slope calculations for edge pixels. The slope algorithm utilizes a 3 x 3 cell window to calculate slope values for given target cells. For example, edge cells with elevations of 1000 meters are compared to adjacent fill cells with values of zero and a large slope value is calculated. A modification of the SLOPE command has been suggested to eliminate fill cells or cell values specified by the user from being included in slope and aspect calculations.

The above examples illustrate some of the known problems associated with DEM and DTT data. Planned modifications to existing software and the potential for new command development will enhance MOSS capabilities for minimizing these problems. In the interim, potential processing alternatives may be available through SC technical and system support.

MOSS ENHANCEMENTS

Limitations to foreseen terrain data entry and processing requirements have been identified for the MOSS software package. Due to the efforts of the BLM SC, Branch of GIS Implementation, a number of potential enhancements have been identified and are being implemented. These efforts will greatly increase MOSS/MAPS terrain data manipulation capability.

SUMMARY

The MOSS environment can currently enter and process 7.5-minute DEM data. Although access to 1:250,000 DEM and 1:250,000 DMA/DTT data is possible within MOSS/MAPS, the process currently involves data transfer capabilities among multiple systems. The direct access to 1:250,000-scale terrain data could be incorporated into MOSS in the future. Current command/function capabilities within MOSS are adequate for the processing of raster elevation data to generate slope, aspect, and other terrain related information, however, edge data handling problems should be corrected. Efforts to provide enhancements to the raster processing command set should continue. Modifications to existing software and limited software development would significantly increase MOSS capability for the manipulation of digital terrain data.

MOSS users should familiarize themselves with potential resource applications and the inherent limitations of digital terrain information. Awareness of potential data inconsistencies and current limits to system processing capabilities will enhance the potential for making digital terrain data a workable component of the MOSS GIS.

REFERENCES

Boyko, K.J., 1982, Production of Digital Elevation Models By Stereomodel Digitizing: Technical Papers--1982 ACSM-ASP Convention, pages 38-47, Falls Church, VA, American Society of Photogrammetry.

Chan, K., 1985, Locating 'Lakes' on Digital Terrain Model: Technical Papers--1985 ACSM-ASPRS Fall Convention, pages 68-77, Falls Church, VA, American Society of Photogrammetry and Remote Sensing.

Dubayah, R.O., and Dozier, J., 1986, Orthographic Terrain Views Using Data Derived from Digital Elevation Models: Photogrammetric Engineering and Reomote Sensing, Vol. 52, No. 4, April 1986, pages 509-518.

Elassal, A.A., and Caruso, V.M., 1983, USGS Cartographic Data Standards-Digital Elevation Models: U.S. Geologic Survey circular 895-B, 39 pp.

Faintich, Dr. M.B., et al., 1984, Terrain Elevation and Surface Feature Data Display for Mission, Land Use, and Trafficability Planning: Proceedings--Pecora 9, pages 278-285, Silver Spring, MD, IEEE Computer Society Press.

Foster, J.W., and McKinley, R., 1986, Expected Grazing Pressure Geographic Information System Model: Abstracts-- Society for Range Management 39th Annual Meeting, Denver,CO, Society for Range Management.

Jensen, S.K., 1984, Automated Drainage Feature Delineation From Digital Elevation Model Data: Proceedings--Pecora 9, page 410, Silver Spring, MD, IEEE Computer Society Press.

Johnson, G.R. and Rohde, W.G., 1981, Landsat Digital Analysis Techniques Required for Wildland Resource Classification: Arid Lands Resource Inventories: Developing Cost-Efficient Methods, pages 204-213, USDA, Forest Service, General Technical Report WO-28, June 1981.

McKinley, R.A., and Maslanik, J., 1985, Digital Elevation Data in Large-Area Resource Studies: Proceedings--Pecora 10, page 428, Falls Church, VA, American Society of Photogrammetry and Remote Sensing.

Keating, B. and Gilson, H., 1984, Unpublished papers and personal communication: January 1984, BLM Service Center, Denver, CO.

McKinley, R.A., et al., 1985, Operational Fire Fuels Mapagesing With NOAA-AVHRR Data: Proceedings--Pecora 10, pages 295-304, Falls Church, VA, American Society of Photogrammetry and Remote Sensing.

Troup, M.I., 1982, Interactive Correction of Digital Elevation Models: Technical Papers-- 1982 ACSM-ASP Convention, pages 305-316, Falls Church, VA, American Society of Photogrammetry.

U.S. Geological Survey,1986, USFS/USGS to Exchange DIgital Elevation Data: Federal Digital Cartography (FDC) Newsletter No. 3, Winter 1986.

Wong, K.W., 1983, Accuracy of Earthwork Calculations from Digital Elevation Data: Photogrammetric Engineering and Remote Sensing, Vol. 49, No. 1, January 1983, pages 103-109.

GIS TRAINING IN THE PROFESSIONAL SETTING: REQUIREMENTS FOR A SUCCESSFUL TRAINING SESSION

Daniel Webster
TGS Technology, Inc.
Denver Federal Center
Bldg. 50, D-442T
Lakewood, CO 80225-0047

ABSTRACT

Over the past 18 months, staff members from TGS Technology, Inc. have worked with the U.S. Department of Interior Bureau of Land Management in presenting 27 training sessions on public domain GIS software packages. Preparing a GIS training course necessitates defining staffing requirements and trainer's responsibilities, as well as preparing course announcements, keeping enrollment lists, and fixing agendas. Course materials must be produced, including slides, texts and graphics. Hardware for a hands-on GIS training session includes CPU, graphics terminals and hardcopy devices. Software requirements include the CPU operating system and the GIS software that is the focus of the training. Hands-on exercises are based on a geographic database reflecting the full array of available data types, and containing a good sampling of thematic information. Lectures present general GIS concepts and specific course topics in a concise manner. Over the past 18 months, greater than 30% of the approximately 330 GIS trainees have become regular GIS users, and nearly 70% have in some way applied GIS to their professional discipline. Beginning with effective pre-planning, a GIS training session that blends lectures with hands-on exercises provides trainees with enough experience to develop GIS applications in their respective disciplines.

Introduction

As Geographic Information Systems (GIS) gain wider acceptance among the planning professions, there is an increased demand for effective training in GIS use and management. Staff members from TGS Technology, Inc. (TGS) and the U.S. Department of Interior Bureau of Land Management (BLM) have developed and presented several types of GIS courses. Course topics have included introductory GIS, advanced GIS, and special topics such as data entry and cartographic output. Group sizes have ranged from 12 to 20 individuals, and attendance to the 27 courses held in the last 18 months has totaled more than 300 people.

The purpose of this paper is to describe one proven method of successfully presenting GIS training in a professional setting. Though this description is based on the experiences of TGS Technology, Inc. and BLM, the intent is to focus on topics and procedures applicable to most GIS training settings. Throughout this paper the BLM course entitled "Introduction to Geographic Information Systems and MOSS" shall be the basis of discussion.

The BLM course "Introduction to Geographic Information Systems and MOSS" is a three and a half day training workshop meant to introduce BLM staff to the basic workings of a GIS, and introduce the use of the Map Overlay and Statistical System (MOSS), a public domain geographic data analysis software package. In general the training session proceeds as follows. Concise introductory lectures make use of slides and text illustrations to describe GIS. The purpose of the initial lecture is to answer the two questions, "What is a GIS?" and "What can a GIS do?" Subsequent lectures grow more and more detailed, explaining types of geographic data, the GIS database, and the essential tools for using a GIS, i.e., the computer hardware and software. A guest speaker presents a short description of how the GIS has been applied to a BLM project.

During the opening lectures, trainees are introduced to hardware and software. The next step is to provide trainees an initial hands-on experience with the system. Each trainee is allowed the opportunity to apply some of the basic operating system procedures, and to become familiar with the CPU, graphics terminal, and line printer used during the training session. Three more short lectures follow: data entry highlighted by a digitizing demonstration, illustrations of data analysis techniques, and examples of output products.

Next, each trainee takes part in another hands-on session, this time concentrating on the more commonly used functions in the GIS software. As the sessions proceeds, the instructors briefly discuss certain data analysis functions and then monitor the trainees' execution of geographic data analysis exercises. The remainder of the training session is dedicated to hands-on learning, with individual attention from instructors. At the conclusion of the course, the trainees are asked to evaluate the session, and suggest means of improving the instruction.

Course Preparation

Course organizational details include staffing requirements, course materials, announcements and enrollments, agendas, physical facilities, and costs. A lead trainer must be designated, i.e. a capable instructor well versed in GIS. A second instructor also should be designated to assist the lead instructor, and to take lead responsibility on short notice. A hardware expert and a software expert should be readily available to maintain the computer equipment, so that in the event of hardware or software difficulties during a training session, comparatively quick remedies will be available without disrupting the continuity of the session. It is important to assign organizational responsibilities to an individual capable of tracking enrollment, waiting lists, text duplication, transportation, and costs. Secretarial support is necessary, particularly for preparation of the letters, memorandums, text manuscripts, and announcements related to the training sessions. Finally, instructional support may be found on occasion by inviting guest lecturers to speak on such special topics as project management or a GIS application.

An ideal staffing arrangement is a team of seven individuals working on training: coordinator, trainer, assistant trainer, hardware specialist, software expert, administrative assistant, and secretary. However, sometimes staff members must assume multiple responsibilities. For example, the TGS training coordinator also serves as lead trainer, and as hardware and software expert. Additionally, the organizational and secretarial tasks are performed by individuals who find time amid their other professional responsibilities to support training activities.

If materials must be developed for a training session, it is well to begin at least six months in advance of the scheduled training date. Materials may include the following: training manual, slides, plots, graphics, geographic data, software documentation, video, and supplementary hand-out information. A training manual should include text and graphics sufficient to address all topics in the training course. Compilation of such a text, along with associated slides, graphics, videos and supplementary information easily may require six to twelve months time. Geographic data is discussed in a subsequent section. Once all course materials are prepared, time must be allowed for text duplication and binding.

Arrangements for training announcements, enrollment, and agendas should begin at least eight weeks prior to a scheduled session. A course announcement is supplied to all interested parties, and contains course title, dates, location, fees, prerequisites, and maximum class size, which in turn depends on the number of graphics terminals used during the training. TGS and BLM have found that for effective exposure to software during hands-on sessions, no more than three students should be assigned to one graphics terminal. If enrollment exceeds predetermined class size, a waiting list must be maintained, and a priority system must be used to determine who is accepted into the session. BLM prioritizes course attendees according to the immediacy of applying GIS subsequent to training. A final course announcement is sent to individuals accepted into a training session. An agenda is prepared for each training session, and includes a daily schedule of lectures, demonstrations, and exercises.

Costs of preparing and presenting a GIS training session should be monitored. Expenditures may include text duplicating, guest lecturers, staff time, hardware leasing, conference room, and transportation. The BLM collects no enrollment fees, as trainees are BLM staff members. However, costs of presenting GIS training sessions sometimes are shared by two BLM offices. If training sessions are held repeatedly in one location, it is possible to engage the services of an organization that specializes in hosting conferences.

Through the course of presenting numerous GIS training sessions TGS staff have encountered and alleviated several problems typical to course preparation: inadequate staffing, over-enrollment, not screening attendees according to pre-requisites, failing to secure guaranteed participation from assistant trainers and guest lecturers, and allowing inadequate lead time for text duplication.

Hardware, Software, and Data

The introductory GIS training presented by BLM and TGS utilizes two Data General Model 20 Desktop Microcomputers, each with 15 Megabytes of disk space. For each microcomputer, two Visual 500 graphic terminals are used as work stations, allowing a total of four workstations for the hands-on portion of the training session. In addition, one Anadex dot matrix line printer is configured with each microcomputer, and is thus shared by two workstations. The course instructors make use of a Calcomp 9100 digitizing tablet and Tektronix 4014 graphic terminal during a demonstration of data entry procedures.

Since the BLM limits the number of course participants to three individuals per workstation, the amount of hardware used in the training session controls the number of people in attendance. Consequently, using four graphic terminals means a maximum of 12 individuals per training. It is worth noting that participants evaluating the BLM training often recommend reducing the number of people per terminal to two, or even one. This would result in a need either to limit the class size or increase the number of workstations.

The microcomputers operate well in a training setting, yet there are some limitations. Once the MOSS/MAPS software is loaded on the system, much of the 15 Mb of disk space is occupied. This results in a need to confine the scope of the geographic database to a rather limited coverage and a small number of data themes. The shortage of disk space means that trainees must take care to avoid exceeding disk capacity when creating derived maps. While the 15 Mb disk is adequate for training needs, a greater disk capacity, such as 30 Mb, would allow for greater flexibility during training sessions. Another limitation of using microcomputers in a training setting is that only a small number of workstations may be configured with each computer.

On occasion, the BLM GIS training session has been held in field locations, and different hardware configurations were utilized. During a training session in Alaska, four Tektronix 4014 terminals, each with a Tektronix 4631 hardcopy device, were used. The CPU was a Data General MV10000. Since the trainees in Alaska were not the only users on the system, arrangements were made with the system manager to assure that system priority was set to enable GIS trainees to interactively process geographic data while avoiding lengthy waits for processing time.

On the day before a training session begins, the hardware must be set up and tested. Proper cables and switch boxes must be tied into the CPU, graphic terminals, and hardcopy device. The system must be configured to accommodate all peripheral devices. It is well to prepare a diagram of the proper wiring of the training hardware, and to label each cable according to its type and purpose. All set-up menus, pin settings, and other hardware dependent communication parameters should be set and then documented for later reference. Other training hardware to be considered are video projectors, slide projectors, screen, overhead projectors, power strips, power extensions, switch boxes, spare cables, and tools such as screw driver and tape.

The TGS and BLM staff have encountered some typical hardware problems during training sessions. These include: mechanical failure which required substituting other hardware for failed components, power failure which resulted in agenda changes and instructional improvising, and improper configuration alleviated by acquiring correct hardware and cables.

Software components for most operational geographic information systems include data capture, data analysis, and graphic output (as well as the operating system software inherent to the hardware being used). BLM makes use of the Automated Digitizing System (ADS), the Map Overlay and Statistical System (MOSS), the Map Analysis Package (MAPS), and the Cartographic Output System (COS), all public domain software. During the introductory GIS training session, ADS is illustrated with a digitizing demonstration, and COS is discussed but not used. BLM's introductory GIS trainings focus on data analysis (MOSS/MAPS), since follow-up courses on ADS and COS are available.

Software maintenance for a GIS training sessions may include a variety of tasks. The software must be loaded onto the computer and proper links between directories must be established. Since the BLM training microcomputers often are put to other uses between training sessions, the GIS software is backed up to diskette and cartridge media for storage, and then erased from disk. Just prior to training, the software is restored to the computer disk. Other software maintenance tasks include cleaning temporary files, deleting files created by trainees, creating new users on the system, and creating new data directories. These procedures should be documented and made available to all individuals responsible for setting up a training session. The GIS software should be fully tested the day before a training session begins. A good test includes logon, data access and analysis, and display of text and graphic data from each user area on the computer.

Typical software problems which may arise during setup of a training session include inadequate disk space and improper user privileges. One solution to shortage of disk space is to simplify the geographic database to a few themes over a small area of coverage. Another possibility is to delete any utility programs that will not be used during training. However, such deletions should not be carried out unless the programs are readily available to be restored to the system when needed. For proper user priviledges it is up to the system operator to assure that each user has access to all directories and programs needed during the training session. A backup of all training software and data should be kept on hand.

In the BLM's introductory GIS training course, a geographic database is provided to the trainees. The database includes vector data (point, line, and polygon), as well as dichotomous, discrete, and continuous cell (raster) data. The coverage includes two 7.5 minute USGS Series Quadrangles in western Colorado, an area administered by the BLM. The training database consists of a variety of thematic information, such as transportation, ownership, wildlife habitat, known geologic structures, surface water, soils, and land cover; all representative of natural resource management GIS applications in the BLM.

The training database should be representative of the data that the trainees will inevitably be using on the job. A geographic database may be custom built for a particular group of trainees. For example, one training session held on site in the BLM's Wyoming State Office did not make use of the Colorado database mentioned in the above paragraph. Instead, staff members from TGS and BLM Wyoming created a geographic database consisting of transportation, elevation, and wildlife data relating to an actual resource management project in Wyoming. Thus, during the course of the training session, trainees were able to learn about GIS applied directly to their Wyoming projects.

The Session: Lectures, Exercises, and Wrap-up

The BLM introductory GIS training course calls for seven lectures to be presented during the three and one-half day session. The first lecture introduces basic GIS concepts, and details the use of hardware and software. A discussion of a GIS application, such as a study of conflicts between archaeological sites and coal leases, is included in the first lecture. The second lecture is an introduction to the computer operating system to be used during the training session, and is followed by a hands-on session so the trainees may gain familiarity with the system. The third lecture presents detailed descriptions of geographic data types, databases, and data themes. A digitizing demonstration accompanies the fourth lecture which focuses on data entry. The fifth lecture is a brief description of the analytic software, and entails a hands-on session to allow trainees direct use of common map analysis commands. Lecture six illustrates the production and use of both interim and final output products. Finally, the seventh lecture is a description of the use of flow diagrams and cartographic modeling in planning and monitoring effective use of GIS analytic capabilities.

Following the seven lectures and introductory hands-on sessions, the instructors present the trainees with six data analysis exercises to be carried out over a two day period. This portion of the course is characterized by intense use of the GIS analytic capabilities, during which time trainees are well monitored and provided with individual instruction. Each exercise is prefaced with a short discussion of the type of data analysis to be executed, such as data reclassification, overlays, distance operations, and raster processing. Trainees are encouraged to make full use of the software documentation provided to them at the outset of the training session.

Exercises are presented in a progression of increasing complexity, and incorporate as many different analytic functions as possible. In addition, the exercises make use of all data types, use a wide variety of data themes, and focus on both large and small scales. Students working on the exercises should be encouraged to create flow diagrams and cartographic models, i.e., to plan their analyses before executing commands. Course instructors should be prepared to challenge exceptional students with advanced applications of the GIS, and to allow time during the training session for individuals to experiment with the software.

As trainees complete the final data analysis exercise, the instructors prepare for the course conclusion. By now the trainees are aware of how a GIS works, and are proficient in the use of the analytic software. The instructors then inform the group about limits to the system, known problems, and upcoming software enhancements. Further discussion pertains to GIS projects within the BLM. Questions related to other GIS systems are answered. Course follow-up information is provided, particularly concerning additional GIS training courses, and use of a GIS user-assistance telephone line. Finally, the trainees are asked to fill out a course evaluation form, which the training staff subsequently uses as a basis for updating and improving the course.

The TGS and BLM training staff has encountered several typical problems which arise during a training session. Often, lectures generate discussion which carries on long beyond schedule. The lead trainer must curtail unimportant digressions, and alter the agenda as situations demand. Data processing of more complex exercises may require time delays, resulting in "dead periods" during which trainees are merely awaiting the system response to their interactive commands. Trainers may fill these periods with individual discussions on project planning, as well as scheduled breaks for coffee or meals. At times, an introductory GIS training session may be attended by individuals with widely varied backgrounds. The diversity of knowledge sometimes detracts from a training session when the instructors dwell on topics which may be new to some but second nature to others. However, such diversity may be turned to an advantage if each trainee is encouraged to share their knowledge during the training session.

Post-Session Activities

Once a training session is concluded, a few tasks remain for the training staff. Computer disk space is cleared of all temporary files and derived maps created during the training session. The hardware must be dismantled and returned to its normal location if necessary, and all repairs should be scheduled and carried out. The training staff maintains a list of trainees, together with their addresses, telephone numbers, and professional disciplines. Guest lecturers are compensated, and accurate records of all costs are kept. The course evaluation forms are reviewed, and viable suggestions and improvements are documented and included in plans for future course updates.

Going On The Road

The TGS and BLM training staff frequently takes its introductory GIS training sessions to field locations. Going on the road has its own set of requirements and problems. If it is necessary to move computer hardware, the training staff must be certain to have on hand high quality travel cases made especially for each component. Preliminary planning must consider the costs and the means of transporting the equipment. Also, it is essential to designate an individual at the site of the field training as a temporary member of the training staff. This on-site staff member should take care of many of the preliminary planning tasks, such as conference room reservation and set-up, duplication of course texts and materials, any necessary use of on-site computer hardware and software, creation of specialized training data and exercises, and maintenance of enrollment and waiting lists.

Conclusion

The training session described in this paper is one means of successfully presenting introductory GIS training in a professional setting. The training presented by the TGS and BLM staff has met with considerable success. Over the past 18 months, greater than 30% of our GIS trainees have become regular GIS users, and nearly 70% in some way have applied GIS to their professional discipline.

We have found that a work-shop style training session runs smoothly and effectively under the following conditions: adequate preliminary planning and preparation, careful testing of hardware and software just prior to the course, concise informative lectures, ample hands-on time for trainees, and the availability of expert hardware and software support.

Given a well planned and effectively delivered training session, trainees come away from an introductory GIS training session with a familiarity derived from using the system in a hands-on fashion. Subsequently,trainees are able to apply GIS to their particular disciplines, develop their skills through user manuals and GIS user networks, take part in advanced training, and in some cases become expert users on their own.

Systems Presentations

(abstracts and papers)

CENTRAL ARIZONA PROJECT
HIGH ACCURACY DIGITAL DATA BASES

Richard Lee Lyons, GIS System Manager
Bureau of Reclamation
Arizona Projects Office
23636 N. 7th Street
P.O. Box 9980
Phoenix, Arizona 85068, USA

Abstract

In November 1985, the Central Arizona Project (CAP) office of the Bureau of Reclamation initiated a pilot program called the Geographic Reference and Information data base (GRID-CAP). GRID-CAP is based on a need to successfully integrate a number of manual data bases, dating back over twelve years, into a functional tool for management of the CAP system of dams and canals.

Initiating the GRID-CAP program has brought into focus a number of new facets in the operation of a Geographic Information System (GIS). The CAP's planned program of hardware and software acquisition was the first step in building GRID-CAP. The Hewlett-Packard HP-9920-T computer was selected as the hardware for the acquisition phase of GRID-CAP. The HP-9920-T represents the latest word in a micro computer whose capability matches or surpasses older versions currently in use, such as the HP-1000. Secondly, AMS/MOSS/MAPS was selected over a number of propietory and non-propriety software currently available to the user community. The initial phases of selection and bringing up the software led into the second phase of the pilot, that of building a data base.

The primary objective of the CAP's GRID-CAP program is to achieve accuracies heretofore not attempted. The base level for GRID-CAP data will be at a scale of 1:600 or 1" = 50'. This level is to be achieved through manuscript output from a Wild B8-S Stereoplotter. In the future, a more direct digital interface will be from the APPS-4 (Analytical Photogrammetric Positioning System) and the AS-11-AM Analytical plotter. The data base thus formed will be the base for which cultural data, affected by the CAP system can be accurately managed and displayed for the public good.

I. Background & History of GRID-CAP

The Arizona Projects Office (APO) of the Bureau of Reclamation has amassed a large volume of data ranging from analog to digital in format. The volume of data has grown over the past twelve years to a point where data retrieval has become a time consuming and unwieldy process. The decision to build a unified digital Geographic Information System (GIS) was made by APO to facilitate the rapid retrieval of data for management and decision making purposes.

Once a decision to acquire a digital GIS was made, a number of steps had to be considered. The initial step was what software and what hardware to acquire. Secondly, what personnel would the GIS require and what would their training entail. Lastly, how would training be performed and who would be selected to be trained had to be decided upon. The decisions involving system selection, personnel selection and training deserve additional mention as to the impact they have on a high accuracy digital data base.

Today, there exist over fifty GIS softwares that all essentially do the same thing, manage spatial data. The critical aspect, as far as APO was concerned, was the retention of data used for engineering applications. After much deliberation the software acquisition that APO made was that of AMS/MOSS.

The selection of AMS/MOSS software was predicated upon the overall design of the software and its rigorous attention to data accuracy and precision. This attention to accuracy and detail is significant if the GRID-CAP is to fully support engineering applications. The next critical factor in building a highly accurate digital data base was selection of people. APO made the decision to use specialists acting as representatives for their respective organizations as trainees. Training from the systems manager level down through user level was carried out on site by vendor personnel. These three critical initial steps, software acquisition, personnel selection and training enabled APO to move confidently into a second phase of development, that of testing and manipulation of input data to meet APO's needs.

II. Meeting APO's Engineering Applications

High accuracy digital data bases are rare today. Most raw data input into current systems is input from a variety of source. One source is data overlain or keyed to a standard map, usually a USGS 7 1/2" Quad. Another common source of data input is data from aerial photographs. A third source is multispectral data derived from digital sources such as Landsat multispectral data. GRID-CAP is designed to be a highly accurate digital data base. It will interface such data as cadastral and survey data at its largest scale.

At the small scale end, GRID-CAP will eventually input thematic data and remotely sensed input. The flow of data into GRID-CAP will begin with the photogrammetric output from a WILD B8S in the form of manuscript data. This data at a scale of 1"=50' or scale of 1:600, is the prime prerequisite to building a high accuracy digital data base. By contrast, a product such as an overlay from USGS Quad map would be of doubtful quality to show a number of themes such as land ownership, survey data and point location data. Scale and accuracy are important in that they are directly related in the cartographic display of data, which lies at the heart of accuracy for GRID-CAP. At a scale of 1:24,000, a point data could be displaced by as under us 40' based just on map scale. Therefore to portray data accurately, a step by step approach to the input of data based on input scale is necessary to insure the accuracy and precision for engineering data. A number of factors have to be examined in GIS input data that are part and parcel to building an accurate data base.

A major factor that will influence the building of a very large scale data base is data volume and defining scale to input ratios, to maintain accuracy criteria. One example would be digitizing an average drainage pattern from a USGS 7 1/2" Quad. This might entail some where in the range of 509,000 bytes of data. A single manuscript, on the other hand, at 1:600 might use 50,000 bytes for a space 1/2" square on the same 7 1/2" Quad. Thus it can be readily appreciated that the higher the accuracy of a digital data base the greater the volume of digital data to be managed in a system. The end result of high accuracy then is a problem of data retrieval and manipulation. The users of GRID-CAP are then faced with a number of options, tape retrieval and storage, or opting for more optimum compromise scale in which to work.

In the fifteen base levels of data to be input into GRID-CAP there are probably areas where a lesser accurate scale such as that of the 1:24,000 scale Quad could be used. Vegetation data, consisting of point and polygon entry might not need the accuracy that survey data requires. Such a non-requirement would then lead to a reduction in digital volume. The choice of scale then lies with the creators of the data once they are guided by cartographic principles to a decision. This pattern is being followed by each creator group of data for GRID-CAP data. To insure a cooperative effort in building GRID-CAP, the APO formed a GIS Steering Committee.

III. GIS Steering Committee

As a GIS is new at APO it was thought that by forming a steering committee unified decision making would be made in a number of areas.

The task of the GIS Steering Committee at APO has been to address on a office by office level their needs and requirements for a GIS. Each department is currently looking into the manner in which it performed manual research and the cost benefit of using a digital GIS. Along with its operations are investigations as to what level of accuracy and precision are needed and the resultant scale needed.

In addition to methods of input are ongoing investigations as to a common medium of communication with on site computers in use at APO.

Another aspect addressed by the GIS Steering Committee is the time frame for data and how far to go back in time to recreate data in a digital format and its results and cost.

In short, the GIS at APO is being carefully brought on line to be a responsive tool for managing the Central Arizona Projects system of canals and dams. A further word of comparison should be made to examine the lengths to which APO's GRID-CAP is going to assure data accuracy and precision.

The accuracy of cartographic standards is set by USGS for domestic products. The scale of the USGS 7 1/2" QUAD is 1:24,000. For DLG products the Quad maps are manually redigitized and are not purely digital products in themselves. Redigitization further degredates the product. The result is a product that GRID-CAP could not use except for thematic portrayal of data where high accuracies are not necessary. Another observation on the use of USGS digital products is in order. Since the Digital Line Graph (DLG) products are not digital in origin, but rather a USGS line map that is redigitized, the DLG product would be less accurate than the line map it is generated from. DLG products do not carry accuracy statements as the line maps they are generated from. GRID-CAP, though in a pilot stage, will eventually input pure digital data from a stereo photogrammetric instrument and input it as a digital data base. The accuracies of data compiled photogrammetrically at a scale of 1"=50' or 1:600 will be accurate based on scale and because they are kept in a pure digital form. This digital manuscript data base will then serve as the framework over which cultural and thematic data can be portrayed with no loss in the engineering accuracy and precision requirements needed by APO.

Conclusion

APO in Phoenix has begun to build a high order accuracy digital data base to support engineering applications. In its approach it has found that it is starting in where others have left off. In order to build a GIS in the most effective manner it began by examination of each of the component parts that make up a GIS. The critical areas were examined with a view to eliminating potential trouble areas. Proper software selection, hardware selection and cross training of acknowledged authorities in their fields initialized GRID-CAP. Following these selections, attention was paid to accuracy and precision of data to maintain quality in the product. Finally to complete the construction of GRID-CAP a steering committee was designated to oversee both current and future engineering applications of GRID-CAP at APO. All these components will then insure a high accuracy digital data base for engineering applications at APO.

CENTRAL ARIZONA PROJECT
GRID-CAP
GEOGRAPHIC REFERENCE AND INFORMATION DATABASE

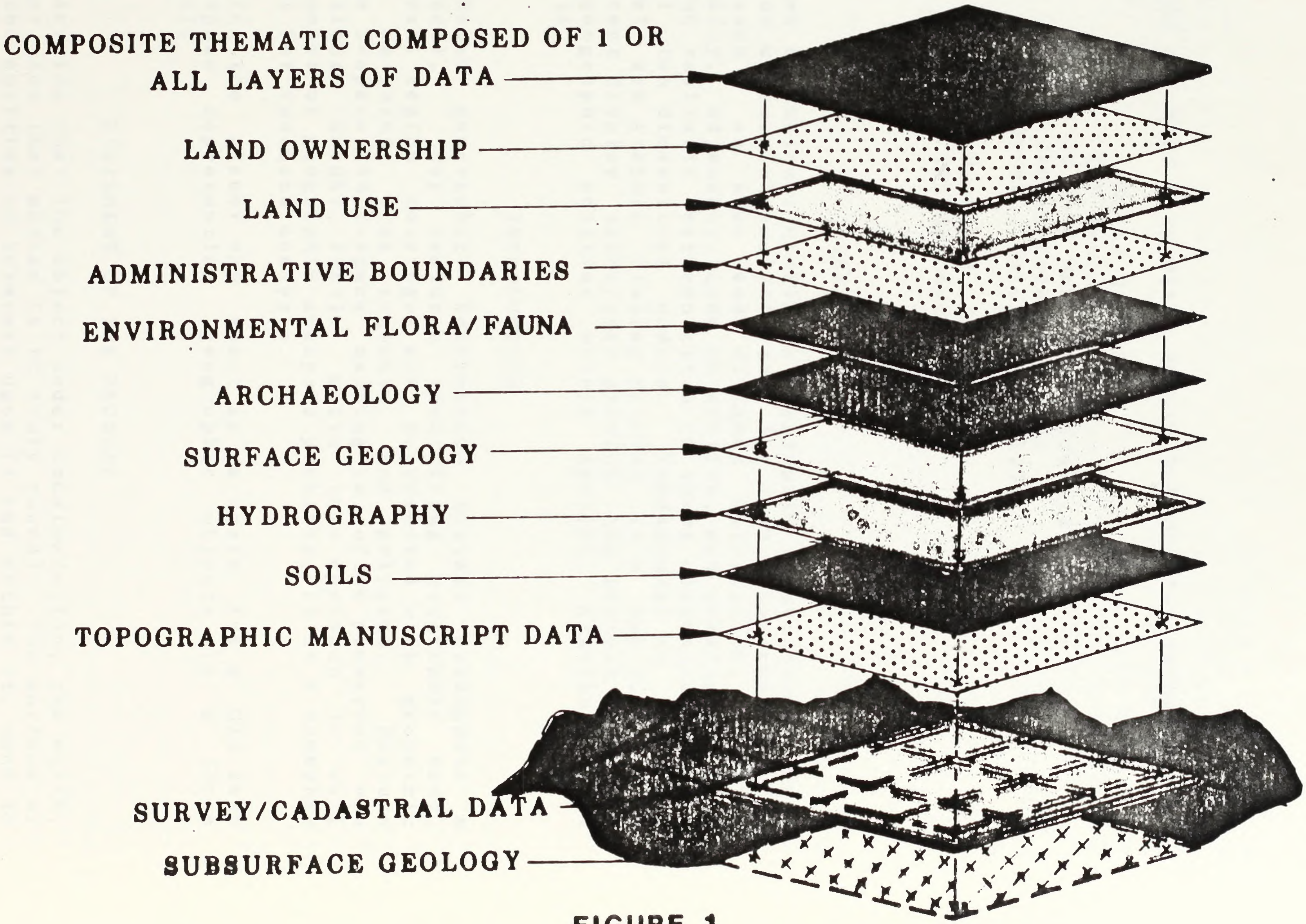

COMPOSITE THEMATIC COMPOSED OF 1 OR ALL LAYERS OF DATA
LAND OWNERSHIP
LAND USE
ADMINISTRATIVE BOUNDARIES
ENVIRONMENTAL FLORA/FAUNA
ARCHAEOLOGY
SURFACE GEOLOGY
HYDROGRAPHY
SOILS
TOPOGRAPHIC MANUSCRIPT DATA
SURVEY/CADASTRAL DATA
SUBSURFACE GEOLOGY

FIGURE 1

Rendering MOSS and MAPS Data Using Modern 3-D Display Techniques

David H. Culley
TGS Technology, Inc.
Bureau of Land Management Operations
Denver Federal Center
Denver, Colorado 80225

Dennis J. Colarelli
TGS Technology, Inc.

ABSTRACT

The use of three dimensional models in geographic information systems (GIS) can provide a powerful analysis tool for land management. Basic GIS functions such as area and distance calculation, viewshed analysis, proximity, adjacency, zone generation, and overlay assume a more natural and realistic representation in three dimensional models than traditional two dimensional models. Fundamental to the three dimensional model are graphic display methods in a two dimensional domain. Different display techniques provide the analyst different ways to view geographic entities within spatial, attribute, and temporal contexts.

INTRODUCTION

Many vector based geographic information systems presuppose a cartographic model. Map features identifying geographic node, network, and areal region coverages are represented with geometric primitives such as point, line segments, and polygons. Feature topology in the 3-space to 2-space mapping is often preserved via projection functions (Snyder, 1982). While this approach is well suited for a number of geographic analysis problems, it is a somewhat restricted model for resource analysis.

Rather than using the planar map sheet as a basis for a GIS data model, we propose representing geographic objects in a three dimensional model.

STATEMENT OF THE PROBLEM

We begin by observing that the object under consideration, the earth, is not flat* (nor, for that matter is it truly round). The surface of the earth, and the entities of interest upon it and within it, tend to be quite irregular in shape. As such, this has posed a difficult problem in modeling the earth. The traditional method has been to make a map of a region, incorporating the desired geographic elements.

---

*The reader is asked to supply a verification from his or her own experience.

Maps prove a popular means of representing the earth due to the wide variety of information that can be stored in a convenient, easily reproducible format. However maps have some inherent drawbacks. One of the primary problems with maps is the loss of geodetic information. In projecting the surface of the earth onto a two dimensional surface, distortion problems associated with area, shape and distance crop up. The severity of this distortion is a function of the projection function used and the map scale (Snyder, 1982). Another is that often, topography is treated as a ancillary theme, and presented in an awkward format, that is marginally useful for quantitative analysis. The result is that it is often neglected in all but the most rudimentary geographical analysis. In many cases these errors are of little concern**. For example, some maps, such as master title plats, census mapping, and subway maps, present primarily topological information (Corbett, 1979)(Marx, 1983)(White, 1984).

Digital modeling of cartographic information in the vector domain is accomplished by representing map features with geometric primitives. Chains of line segments are used to represent network features such as roads, streams, migration routes, boundaries, etc. Polygons are used to bound areal features such as cover types, timber stands, lakes, etc. Points are used to represent nodal features such as cities, houses, oil wells, etc. This sort of representation fails to provide a satisfactory framework for geographical modeling as it implies that there are three immutable, qualitatively different and unrelated classes of phenomena (Cox, 1980); that is, one man's point may be another man's polygon.

THREE DIMENSIONAL MODELING

By representing geographic entities with a three dimensional model we may circumvent some of the problems associated with a cartographic model. Digital three dimensional modeling is used in a number of disciplines, such as stress analysis, parts design and manufacture, and image synthesis. The concept of using three dimensional modeling in geographic information systems is neither new nor revolutionary (Gibson, 1982)(Peuquet, 1984). However, in terms of implementation and application, the majority of 3-D geographic modeling tends to fall into the grid cell model domain. While this approach is suitable for a wide class of problems, the inherent topology is cell based and not feature based.

Two other techniques for representation, analysis, and synthesis of three dimensional shape information are composite surface modeling and finite element modeling. Composite surface modeling consists of dividing the surface of an object into an assembly of curvilinear quadrilateral "patches" (Ferguson 1963)(Coons, 1964)(Catmull, 1978)(Blinn 1982). Finite element modeling is based on decomposing surfaces into regular polygons, typically triangles and planar quadrilaterals (Irons, 1980). The use of curvilinear patches is used extensively in image synthesis and computer aided design (Catmull, 1980)(Faux, 1979), however, due to the complex shapes of geographic entities, the simpler finite element techniques may be better suited for geographic shapes.

**Famed frontier guide Jim Bridger drew maps with charcoal on buffalo hide. They were considered the most accurate in the West.

Input Data

Data for geographic finite element models can come from a variety of sources. For terrain models, data can come from topographic maps, digital elevation models (DEM's), stereo satellite imagery, side radar, etc. Non-terrain models can also be built using geo-magnetic, gamma radiation, or population samples to perform density contouring (Tobler, 1979) and probability surface mapping (Averack, 1984). Clearly, one of the advantages of finite element modeling is the ease of assimilating these various data types into a single uniform topological data type.

GIS Operations

Many of the traditional cartographic analytic operations take on a new meaning when applied in three dimensions.

The concept of distance between two features in the cartographic domain at worst is the 2-D Pythagorian distance on a map sheet, and at best incorporates great circle calculations. Contrast this with a 3-D model where distance minimally assumes three coordinate components, and may accommodate terrain features. Associated with the distance concept are zone generation and proximity operations. As with distance, we have very different results with a surface/volume model than with a planar model.

Area measurements in a 3-D model will approximate the true surface area of the terrain, rather that the surface area of a 2-D projection. Volumetric analysis is somewhat ambiguous and ill-defined in a 2-D model, yet completely straight forward in a 3-D model.

The concept of feature overlay takes on new meaning in three dimensions. Intersection, union, and difference operations on points, lines, and areas can be performed on volumes as well.

GIS operations usually associated with grid cell models, such as slope, aspect, and viewshed analysis occur quite naturally with 3-D finite element models.

Display Techniques

It is evident that a great deal of the power of geographic information systems is the ability to graphically display geographic data. The view of the model may take on many forms, but is usually modeled after traditional cartographic standards. This is only natural, as the digital model is cartographically based.

Three dimensional models provide for a variety of views of a geographic region. As the 3-D model is one step closer to reality than the cartographic model, more realistic simulations are possible. Perspective views of the model often give a clearer picture of a region than overhead views.

The display of 3-D models can be either line drawings, continuous tone images, or a combination of the two. Lighting models can be used to graphically portray areas which are shaded from the sun. Elements of the model can be pseudo-colored to identify attribute information, such as elevation, aspect, vegetation, and soil types. Elements may also be pseudo-colored based on weighted univariate or multivariate functions operating on attribute data. Contour lines can be overlayed onto surfaces to indicate regions which are stratified by elevation. All of these techniques can be used to yield a truly informative, dramatic picture of a region*** . Of course, the 3-D model does not preclude generation of traditional cartographic displays when they are appropriate.

APPLICATIONS

Lets look at some examples where a 3-D model would be useful for resource analysis****. Surface analysis (slope, aspect, area viewshed analysis) can be used for site evaluation in applications such as range suitability, expected grazing pressure determination, grazing allotments, erosion studies, and wildlife habitat studies. Volumetric analysis can be used for for hydrologic studies and subsurface mineral assessment. As 3-D models present a consistent representation of geographic features, simulation studies are a natural extension of this technique.

EPILOG

Maps and map analysis have been with us for a very long time. So much so that it is difficult to conceive of doing things differently. Computers allow us to free ourselves from some of the constraints imposed in modeling three dimensional entities in two dimensions.

In this light, we quote from the 1884 science-fiction classic about life in a two-dimensional world: "Flatland: A Romance of Many Dimensions", by Edwin A. Abbot.

> 'An unspeakable horror seized me. There was a darkness; then a dizzy, sickening sensation of sight that was not like seeing; I saw a Line that was no Line; Space that was not Space; I was myself, and not myself. When I could find voice, I shrieked aloud in agony, "Either this is madness or it is Hell." "It is neither," calmly replied the voice of the Sphere, "it is Knowledge; it is Three Dimensions: open your eye once again and try to look steadily."
>
> I looked, and, behold, a new world! There stood before me, visibly incorporate, all that I had before inferred, conjectured, dreamed,...'

***Although in the spirit of proper Christian temperance, they should probably not be used simultaneously.

****The authors are computer scientists, not geographers, geologists, or resource specialists, hence the examples have been gleaned from applications at the BLM.

REFERENCES

Averack, R. and Goodchild, M. F., 1984. "Methods and Algorithms for Boundary Definition," Proceedings of the International Symposium on Spatial Data Handling, vol. 1, pp. 238-250

Blinn, J. F., 1982. "A Generalization of Algebraic Surface Drawing," ACM Transactions on Graphics, vol. 1, no. 3, pp 235-256.

Catmull, E., 1975. "Computer Display of Curved Surfaces," Proceedings of the IEEE Conference on Computer Graphics, Pattern Recognition, and Data Structures, May 1975

Catmull, E. and Clark, J., 1978. "Recursively Generated B-spline Surfaces on Arbitrary Topological Meshes," Computer-Aided Design, vol. 10, no. 6 pp. 350-355

Coons, S. A., 1967. "Surfaces for Computer Aided Design of Space Forms," Report MAX-TR-41, Project MAC, M.I.T.

Corbett, J. P., 1979. "Topological Principles in Cartography," Technical Paper No. 48, U.S. Bureau of the Census, December 1979

Cox, N. J., Aldred, B. K., and Rhind, D. W., 1980. "A relational data base system and a proposal for a geographical data type," Geo-Processing, vol. 1, pp. 217-229

Ferguson, J. C., 1964. "Multivariate Curve Interpolation," Journal ACM, vol. 11, no. 2, pp. 221-228

Gibson, L. and Lucas, D., 1982. "Spatial Data Processing Using Generalized Balanced Ternary," Proceedings of the IEEE Computer Society Conference on Pattern Recognition and Image Processing, June 1982

Faux, I. D. and Pratt, M. J., 1979. "Computational Geometry for Design and Manufacture," Ellis Horwood Limited, Chichester.

Irons, B. M. and Ahmed, S. 1980. "Techniques of Finite Elements", John Wiley & Sons

Marx, R. W., 1983. "Automating Census Geography for 1990," American Demographics, June 1983

Peuquet, D. J., 1984. "A Conceptual Framework and Comparison of Spatial Data Models," Cartographia, vol. 21, no. 4, pp. 66-113

Snyder, J. P. "Map Projections Used by the U.S. Geological Survey," Geological Survey Bulletin 1532

Tobler, W. R., 1979. "Smooth pycnophylactic interpolation for geographical regions," Journal of the American Statistical Association, vol. 74, pp. 519-530

White, M. S., 1984. "Technical Requirements and Standards for a Multipurpose Geographic Data System," The American Cartographer, vol. 11, no. 1, pp. 15-26

An Illustration

The figures on following pages illustrate how a contour map may be transformed into a finite element model. For clarity, the contours in this illustration are topographic.

Figure 1A is a section of a typical topographic map. The contours are represented by connected line segments. Each of the contours represent a surface elevation. Figure 1B shows the triangulation of the contour lines. The lines which bridge the contours connect at the contour verticies in a way which minimizes their length.

Figures 2A and 2B show the models from an elevation angle of 60 degrees. The contours have been translated to their true spatial location. Figures 3A and 3B have been rotated another 20 degrees. Note that the finite element illustration shows all of the edges of the elements.

Figures 4-6 show the model from an elevation angle of 10 degrees and azimuthal rotations of 30, 60, and 90 degrees, respectively. The finite element model in these figures have the hidden edges removed.

All current software developed for the triangulation and display process reside on XT level microcomputers. Display output was generated on a Tektronix 4027 and an HP 7400 plotter. A series of color smooth shaded pictures were produced of the triangulated model.

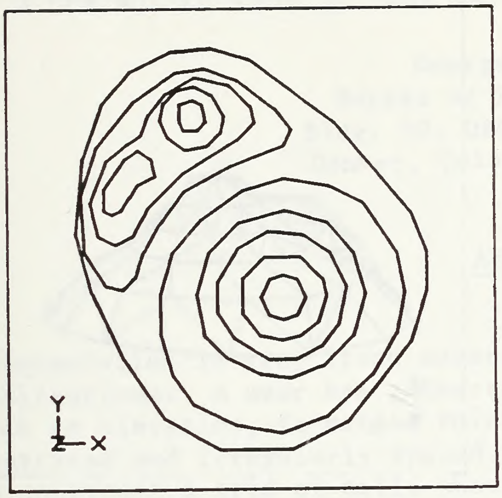


Fig. 1A

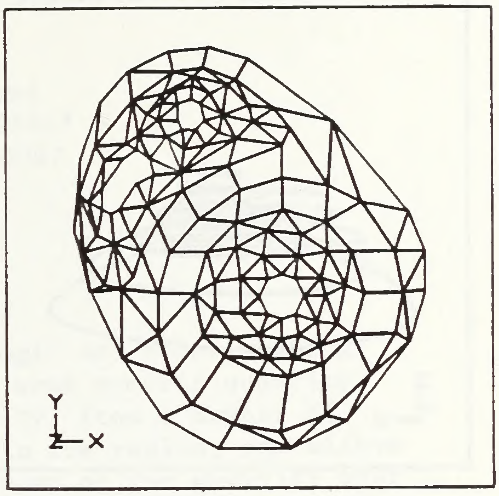


Fig. 1B

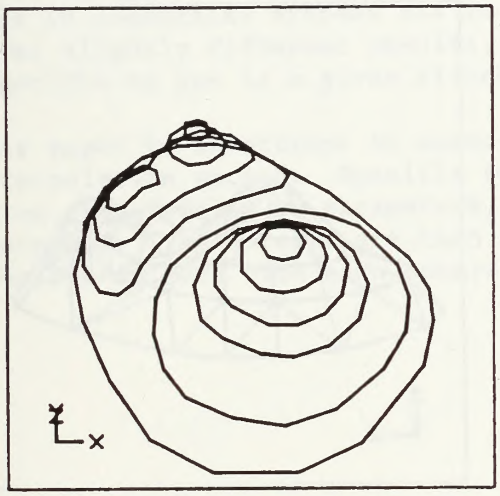


Fig. 2A

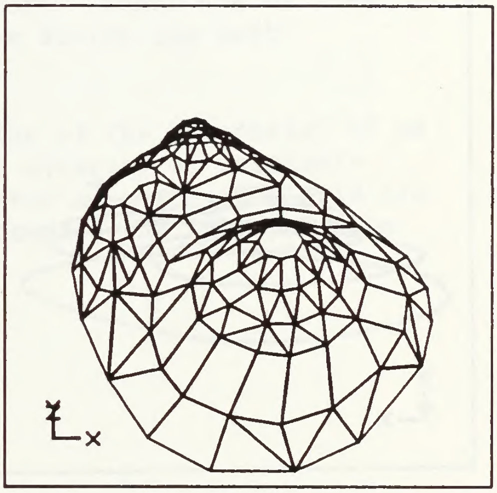


Fig. 2B

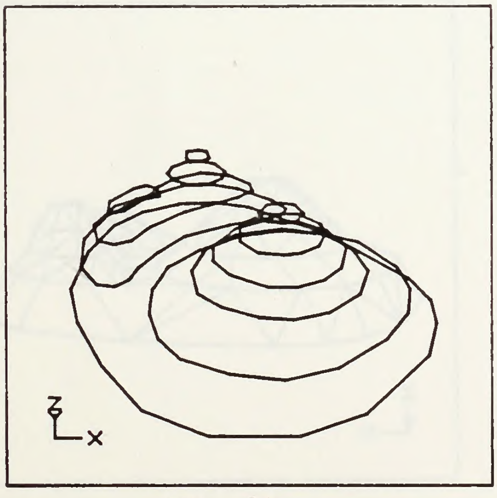


Fig. 3A

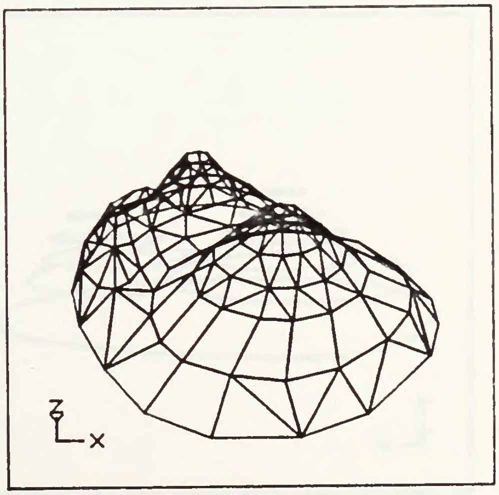


Fig. 3B

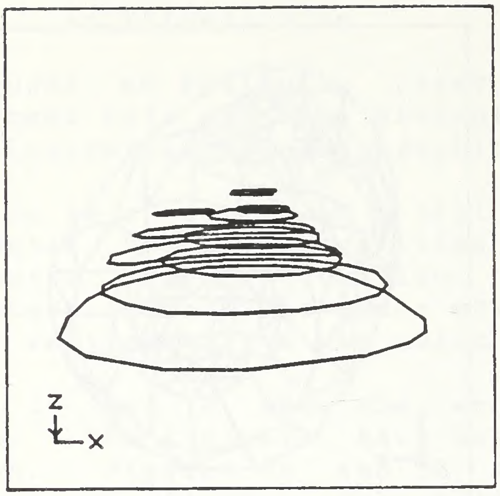


Fig. 4A

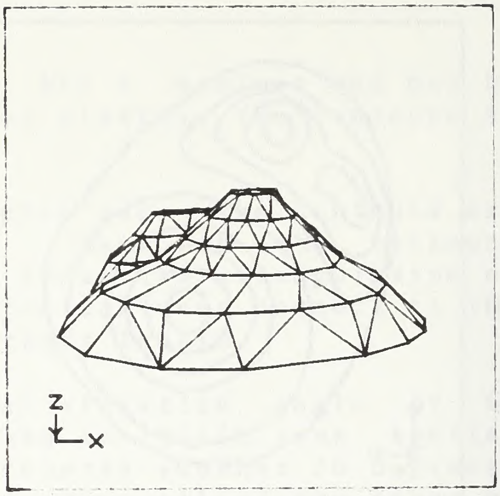


Fig. 4B

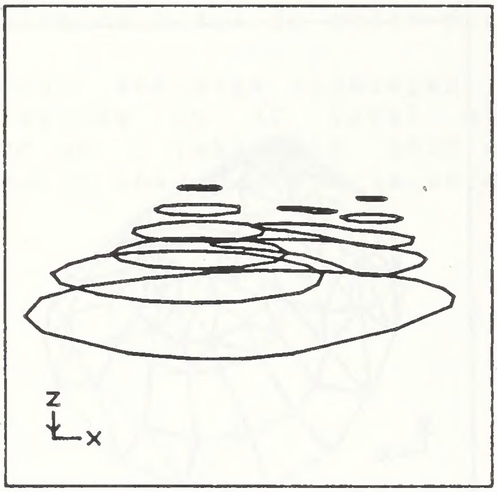


Fig. 5A

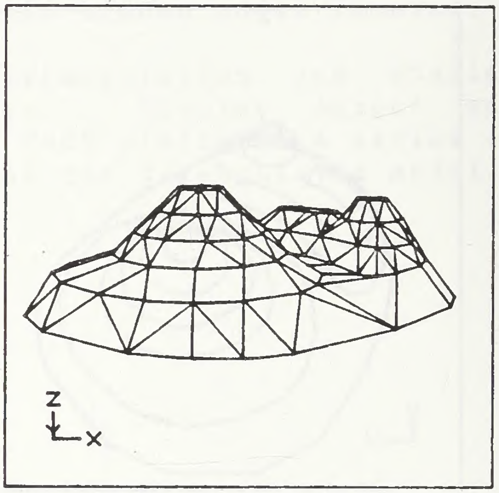


Fig. 5B

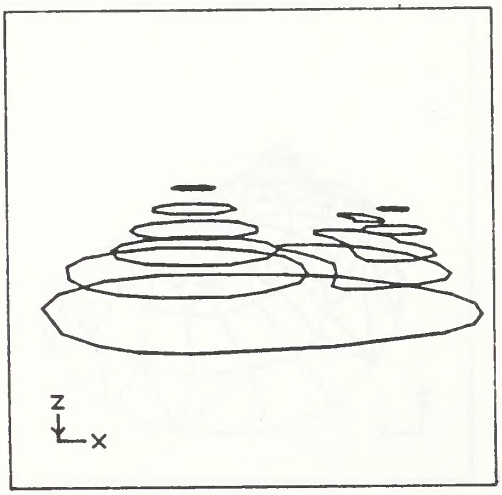


Fig. 6A

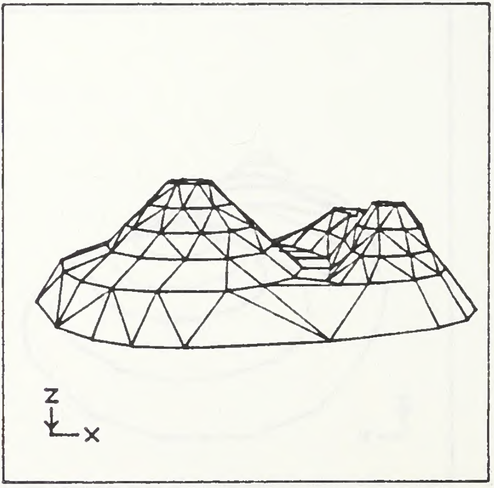


Fig. 6B

A CONTROLLED STUDY OF SOME TWO-DIMENSIONAL INTERPOLATION METHODS

George W. Heine
Bureau of Land Management
Bldg. 50, DFC, P.O. Box 25047
Denver, Colorado 80225-0047

ABSTRACT

Interpolation is very often necessary in geologic and other mapping applications. A user has gathered data about some numeric quantity, such as elevation, formation thickness, porosity, from a number of scattered and irregularly spaced data points in the region, and wishes to construct a grid of cells showing the behavior of the quantity over the entire region. The grid can then be used to produce a contour map, 3-D display, or for various kinds of analysis.

There are presently four interpolation algorithms in MOSS, and many more in commercial systems and in the literature. Every one of them gives slightly different results. How can one decide the best algorithm to use in a given situation?

This paper is an attempt to quantify the notion of the "goodness" of an interpolation method. Specific tests for the accuracy of interpolation, sensitivity to parameters, and smoothness of the output grid are presented. These tests are then applied to compare the interpolation routines in MOSS with each other.

The study described below had its origins in a problem encountered by petroleum geologists in the Bureau of Land Management (BLM). In a producing oil field, there may be subsurface data from a number of wells scattered over the field. The geologist would like to know whether a reservoir underlies a parcel of government land. This parcel may not contain any wells itself. Thus, he needs to interpolate from the data at well sites to predict geologic behavior at non-well sites.

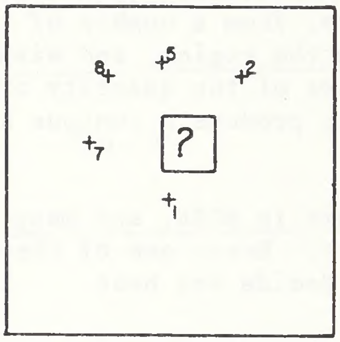


Figure 1

In 1985, the Service Center (SC) of the BLM undertook a study to determine the kind of computer algorithm that might best help the geologist in this situation.

The basic problem in interpolation can be stated as follows: Given a set of data points in the plane P_1, P_2, ... P_n, each of which has a Z-value associated with it, Z_1, Z_2, ... Z_n, and given a point or cell P_o, find a reasonable Z-value to associate with P_o (see Figure 1). Ordinarily the interpolation procedure is repeated throughout a rectangular grid to create a grid of cells, as shown in Figure 2. This grid can then be used to produce contour maps, 3-D displays, or various kinds of analyses. For the geologist, the data points might represent drill hole sites and the Z-values would represent depth of a formation, thickness of a formation, or a geophysical/geochemical parameter such as porosity or pressure. There are applications to other fields such as meteorology, bathymetry, and soil science.

10	9	7	5	1	0
9	8	5	4	2	1
8	7	6	2	2	1
8	7	4	1	1	0
8	5	2	1	0	1
8	6	4	2	0	0

Figure 2

Interpolation algorithms in use seem to fall into two broad categories: statistical and geometric. The statistical model assigns a weight to each data point, based on its spacing relative to P_o, and then computes a weighted average. The geometric model finds a bivariate function f (x,y) which takes on the value Z_i at each data point P_i and satisfies certain criteria of continuity and smoothness. (In some geometric models, the requirement that the function exactly match all known Z-values is relaxed.)

STATISTICAL ALGORITHMS

Inverse-Distance Weighted Average: In this method we assume that the importance of a data point to the calculation of P_o varies inversely with its distance. Thus, each data point is assigned a weight equal to 1 divided by its distance from P_o. A data point 300 feet away would have half the importance of a data point 150 feet away, which in turn would have half the importance of a data point 75 feet away. If P_o happens to coincide with a data point, it is simply assigned the Z-value of that point.

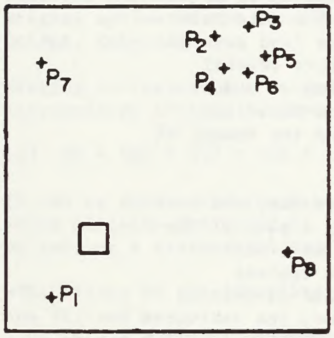


Figure 3

Mathematically, we say that:

$$Z_o = \left(\frac{1}{d_1}\right)Z_1 + \left(\frac{1}{d_2}\right)Z_2 + \cdots \left(\frac{1}{d_n}\right)Z_n \qquad (1)$$

In practice, it is perhaps more common to use the inverse of the square of the distance, rather than the inverse of the distance, as a weight:

$$Z_o = \left(\frac{1}{d_1}\right)^2 Z_1 + \left(\frac{1}{d_2}\right)^2 Z_2 + \cdots \left(\frac{1}{d_n}\right)^2 Z_n \qquad (2)$$

In a real situation with hundreds or thousands of data points, computation needs to be limited in order to be done in a reasonable amount of time. This is done by considering only points within a specified neighborhood of P_o, by taking only the closest data points up to a certain maximum or (usually) both. Preliminary results of this study show that this kind of limitation can actually increase accuracy.

One objection to the inverse distance weighting algorithm is that it does not handle clustered data well. In Figure 3, the Z-values at points P_2 - P_6 would probably affect the calculated value more than the closer point P_1, simply because there are more of them.

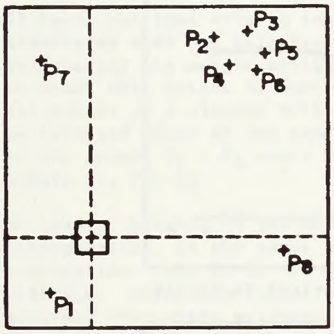


Figure 4

Quadrant (Octant) Weighted Average. These algorithms are a modification of inverse-distance which attempt to correct the problems associated with clustered data. Rather than select only the closest points to a cell for use in the weighting, an equal number of points are selected from each quadrant. This ensures that the calculated cell value will depend on data from all directions and will be more independent of the clustering effect. Thus, in Figure 4 only the points Z_2 and Z_4 might be selected from the large cluster of data points.

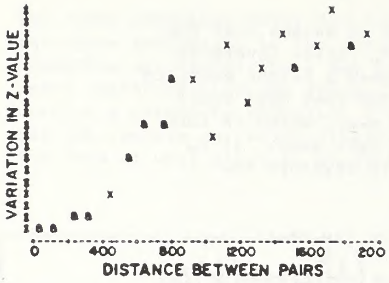


Figure 5

Kriging. This method is an alternative to both inverse-distance and quadrant-weighted algorithms. In kriging, rather than assume that the importance of a data point varies inversely with the distance to P_0 or with the square of the distance, in kriging the user analyzes the data himself and generates a mathematical function (called the covariance function) representing his best guess as to how the influence of a data point varies with distance (and perhaps direction). He enters several parameters to represent this function, including the kind of model (spherical, exponential or linear), the amount of random variation present (or "nugget effect"), the range of influence and the amount of variation when points are far apart (or "sill").

To determine the relationship between variation and distance, the user or program constructs a variogram. This is essentially a plot of the average squared difference in Z-values on the vertical axis with distance between data points on the horizontal axis. A typical variogram is shown in Figure 5. The further apart a pair of points, the less relation there is between their Z-values. Thus, the variogram should rise from left to right.

Sometimes the user may suspect that direction, as well as distance, should be a factor in the interpolation. For example, perhaps data points lying east or west of P_0 should have more weight than those lying north or south of P_0. This can be investigated by constructing variograms using only pairs of points whose relative orientation is approximately north-south, or approximately east-west. (Or any other direction.) If it seems appropriate, these "directional variograms" can then be entered in the kriging computations.

Having constructed a variogram, the user attempts to find a mathematical model which it approximately fits. This model becomes the covariance function for the kriging program. The two most command models are shown in Figures 6 and 7.

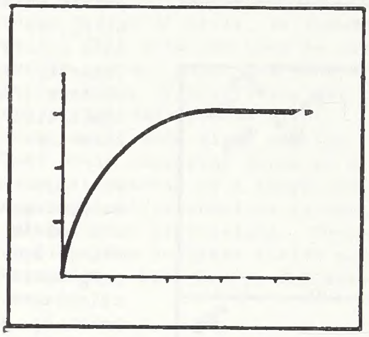


Figure 6. Spherical Variogram

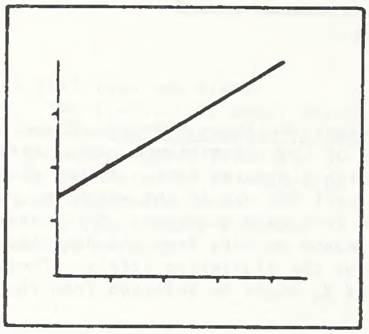


Figure 7. Linear Variogram

There are:

(3) spherical model: $f(h) = S\left[\frac{3}{2}\left(\frac{h}{r}\right)^3 - \frac{1}{2}\left(\frac{h}{r}\right)\right]$ for $0 \leq h < r$;

and $f(h) = S$ for $h > 1$;

(4) linear model: $f(h) = \left(\frac{S}{r}\right)h$ for $h \geq 0$;

where s represents the sill, and r the range of influence.

In some implementations of kriging, the covariance function is computed automatically. This is done, for example, in the commercial kriging software marketed by Geomath, Inc., Wheat Ridge, Colorado and in the kriging option of the gridding package marketed by Golden Software, Golden, Colorado.

Kriging is basically a weighted average computation in which the interpolated Z-value is expressed by:

(5) ZO = (W1 * Z1) + (W2 * Z2) + ... (Wn * Zn) .

It can be shown that there is a unique set of weights (W1, W2, ... Wn), which minimize the error in (5), and that these weights can be computed by solving a system of linear equations whose constants include:

-The values of the covariance function f(PO,Pi) between Po and each of the Pi; and
-The values of the covariance function f(Po,Pj) at each pair of data points.

It turns out that kriging completely solves the clustering problem associated with the weighted-distance algorithm. This is because in calculating the weight assigned to each point, a term for its closeness to other data points is subtracted. Thus, the total contribution of all points in a cluster will be about the same as the contribution of an isolated point at the same distance. For example, in Figure 3 each of the points P_2 - P_6 would have about a fifth of the weight of the points P_1, P_7, P_8.

In theory, kriging is the best possible weighted average method of interpolation, in the sense that it minimizes the expected error due to computation. But it is not necessarily always the best method in practice. Kubik and Botman, 1976, showed that the improvement in accuracy over other weighted average methods might be insignificant. Kriging computation, solving a system of linear equations at each grid cell, is time-consuming and costly. The question arises whether the extra accuracy is worth the effort. This is one of the questions we hope to address in this study.

George Matheron and his collegues have developed an extension to kriging known as universal kriging. Universal kriging takes account of regional trends in the data. The idea of a trend can perhaps best be explained by a one-dimensional analog. Figure 8 is a "scatter diagram" of the kind found in many sciences. We could assume that, other things being equal, the Z-value of an unknown point tends to equal the mean Z-value of all data points. An interpolating line might then look something like Figure 9, tending toward the flat line when far from data points. A more accurate interpolation would be something like

Figure 10, where, other things being equal, the interpolation would tend toward the regression line. In this case, we could say that the points have a "linear trend". In the two-dimensional case, universal kriging allows the program to take account of known trends in the X direction, the Y direction or both.

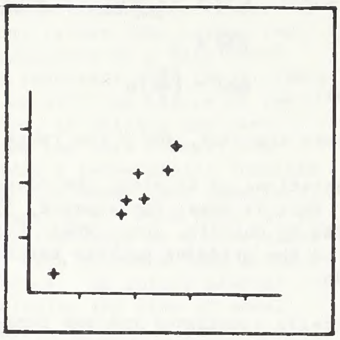


Figure 8

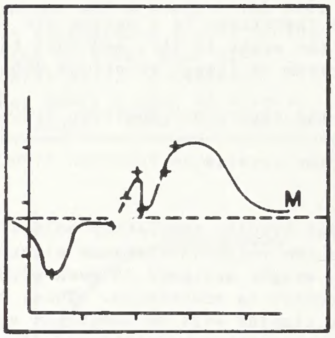


Figure 9

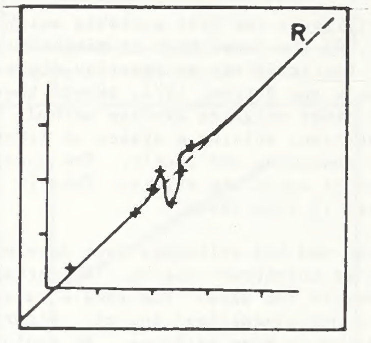


Figure 10

GEOMETRIC ALGORITHMS

All geometric interpolation methods begin by dividing the surface into a network of triangles, with the data points as vertices (Figure 11). The Z-value of a grid point is then related to the Z-values at the vertices of the triangle which contains it. The method of generating the triangles is important. In general, one wants to make the average triangle as nearly equilateral as possible, while at the same time minimizing the average distance between a point and the vertices of the triangle containing it.

Planar Interpolation: The Z-value of a point is considered to lie on the plane determined by the three vertices of its triangle. This is the simplest geometrical interpolation method. The surface produced by planar interpolation is a crystal-like series of flat faces (Figure 12).

Spline Interpolation: In order to produce a smooth rather than crystal-like surface connecting the data points, cubic, quintic or higher-order polynomials are often used. The user searches for a function in which first, second and sometimes higher derivatives are continuous at every data point. Visually, this means that sharp edges and peaks are eliminated. The simplest function that can satisfy these conditions is a set of bivariate cubic polynomials, defined on every triangle. A spline function can be made to satisfy additional conditions besides continuity of derivatives. For example, if the slope is known at some points, these can be entered.

A splined surface is visually much smoother than a surface created by planar interpolation, with all the peaks and angles gone (Figure 13). It has the additional property of being able to predict local maxima and minima in the interiors of the triangles.

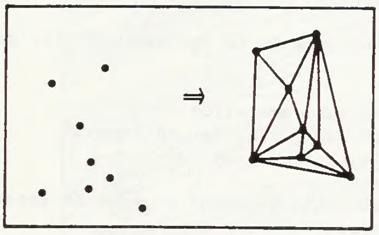


Figure 11

INTERPOLATION METHODS SELECTED FOR TESTING

Four interpolation programs were tested during the initial phase of this study. These four are part of the Map Overlay and Statistical System (MOSS), an automated mapping package that is used by the BLM and several other federal agencies. At the time of publication, efforts were being made to obtain, for testing purposes, a number of other commercial and public-domain interpolation programs.

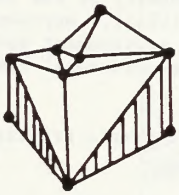


Figure 12

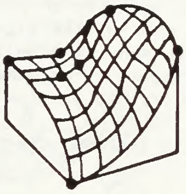


Figure 13

Description of the four programs follow:

WEIGHT. An inverse-distance weighted algorithm developed by Autometric, Inc. The user selects the maximum size of the neighborhood from which data points to be used in the calculation may lie. Eight data points are used (if eight points can be found within the neighborhood). This value of eight cannot be altered by the user.

QUAD. A quadrant-weighted distance program, originally developed by at BLM and since modified by Autometric, Inc. The user can select the maximum size of the neighborhood in which data points used may lie. One point from each quadrant is selected (provided a point can be found within the neighborhood).

SS2DGAMH - SS2DGRID. A variogram-kriging package synthesized by W.D. Grundy of the U.S. Geologic Survey from programs written by Knudsen and Kim, Skrivan and Karlinger, and Journel and Huijbregts. The program produces up to five variograms which the user must examine manually to find values for variogram parameters. The kriging program allows user input of maximum number of points used (up to 50), maximum search radius, drift term exponents for universal kriging and parameters for up to five variogram models.

IDSFFT. A quintic splines program developed by Hiroshi Akima at the Institute for Telecommunication Sciences and published as ACM algorithm number 526. Continuity is based on first and second derivatives estimated at each data point by comparing its Z-value with Z-values of neighboring data points. The user is allowed to select the number of nearby data points used in this estimation, with a maximum of 10.

TESTING CRITERIA

The following seem to be desirable traits for any interpolation algorithm:

- Ease of implementation
- Ease of use ("user friendliness")
- Short execution time
- Accuracy
- Insensitivity to minor changes in parameters ("robustness")
- Smoothness

The first two criteria are certainly important, but are too subjective to evaluate here. Execution time is important and capable of being measured, but seems to be more a property of the code, the compiler and the hardware than of the algorithm itself. Moreover, all testing for this study was done in a multi-user environment and time measurements were not reliable. Thus, except for occasional remarks, this factor could not be evaluated.

Methods of testing the other three criteria are explained in detail below.

Accuracy. In order to test the accuracy of an interpolated surface, it is necessary to have a control surface with which to compare it. The simplest way to obtain a control surface is by mathematical simulation, using a bivariate function f(x,y). Once the surface is obtained, random points are selected and the algorithm is used to recreate the surface.

The choice of an adequate simulating function presents a problem. To our knowledge no work has been done towards establishing the kinds of functions that adequately model terrain or subsurface features. Franke, 1979, includes among his simulations a model of Gaussian hills, a cliff, and a saddle, but the work of Morrison, 1971*, indicates that very simple functions may have different interpolation properties from the complex structures of real terrain. Madelbrot, 1982, has used fractal geometry to produce some models that are visually impressive, but there does not seem to be a way to measure whether they do indeed, model real terrain.

Actual surfaces can of course be used, but areas in which the terrain is known and digitized in sufficient detail are difficult to find. And the use of actual surfaces begs the question to some extent, because the problem then becomes to find a "typical" surface.

---

* See, for example, Table 4.7 on page 54 of this study. Morrison did not explicitly study the effect of the terrain model, but it is clear from his remarks that he was aware of the problem.

Two surfaces were finally selected for the initial study. The first was a complex surface used by Morrison, 1971, (Figure 14). Visually, it appears to simulate a rolling hill and valley terrain. It is generated by a trigonometric series polynomial having about 50 terms. The second was a digitized model of mesa terrain in the Wolf Ridge quadrangle of northwest Colorado (Figure 15).

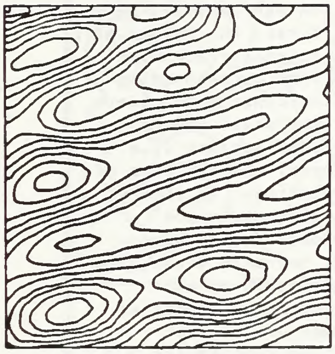


Figure 14. Morrisson's Surface

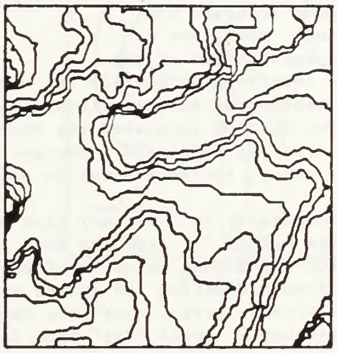


Figure 15. Wolf Ridge DEM

Morrison and Franke, as well as Oden and Meinhold, 1986, studied the effect of distribution of data points on the success of the interpolation; scattered or clustered data points invariably yielded much worse results than evenly spaced ones. Unfortunately, this is the kind of data that the field geologist in the BLM typically has to work with. In a given area, a great many wells may be clustered in an area of known production, with only scattered 'wildcats' in between.

The test data points selected for this study are copied from the actual field locations of oil wells in Riley Ridge, Wyoming (Figures 16-18). Three sets of points were selected, containing 43, 53, and 367 points, respectively.

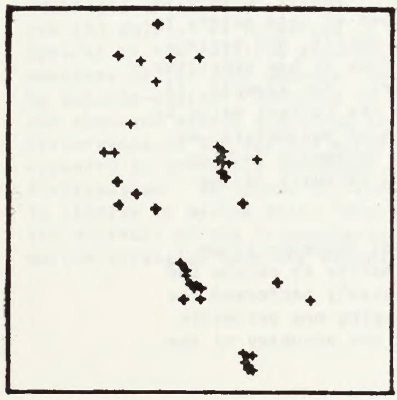


Figure 16. 43 Point Data Set

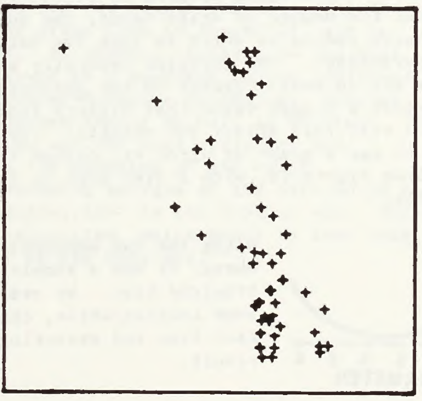


Figure 17. 53 Point Data Set

The accuracy of the interpolation was measured in two ways. First, the values of the interpolated surface were subtracted from corresponding values on the control to obtain a residual surface. The mean of the residual surface (i.e., the mean error) was the bias of the interpolation. In theory, none of the interpolation methods studied should have significant non-zero bias. The standard deviation of the residual surface was taken as the first measure of the accuracy. The smaller its value, the more closely errors were clustered about zero, and thus, the more accurate the interpolation. Next, the correlation coefficient of the control and interpolated surface was measured. This second calculation produced a measure of accuracy independent of the surface being modeled. For display purposes, the correlation coefficient was subtracted from one to obtain a measure for which, likewise, the smaller the value, the more accurate the interpolation.

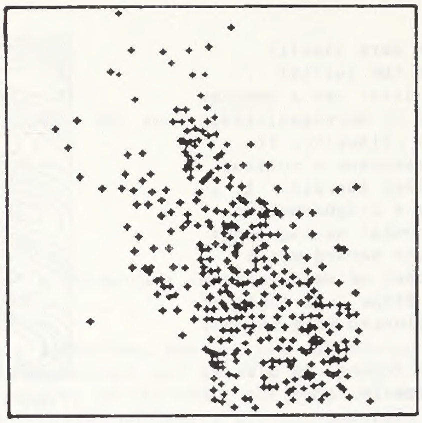


Figure 18. 367 Point Data Set

It was noticed early in the study that some algorithms produced extremely bad values far from the data points, differing from the control values by almost an order of magnitude. To prevent these few bad values from distorting the entire measure of accuracy, the accuracy of interpolation in areas "near" the data points was studied separately from the accuracy in areas "far" from data. "Near" the data points was given the ad hoc definition of "within 500 meters east-west or north-south from the nearest data point". (Note that the overall dimension of each study area is about 10,000 meters square. The grid we were fitting was approximately 200 meters per cell.)

Robustness. Most interpolation systems require some numerical input from the user. The kriging program in particular required answers to prompts about the number of drift terms, the number of data points to use, the search radius in which to look for data points, and various variogram parameters. The question naturally arises of how sensitive the results are to small changes in the parameters. For example, if the user enters a nugget value that differs from the correct value by 1%, how much will this affect the results? For most parameters, we would hope to see a graph of error vs. change in parameter looking something like Figure 19, with a flat area in the vicinity of the optimum value.

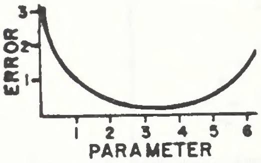


Figure 19

Using the two measures of accuracy given above, it was a simple matter to obtain the required plot. We repeatedly performed the same interpolation, changing one parameter each time and measuring the accuracy of the result.

Smoothness. Consider the two maps in Figures 20 and 21. Given that they are equally accurate, most people would probably prefer to work with Figure 21 with the smoother, simpler contours. We have borrowed the smoothness measure from the theory of splines:

First order smoothness:

$$(6) \quad L1(f) = \int_A \left[f'(x,y) \right]^2 dA$$

Second order smoothness:

$$(7) \quad L2(f) = \int_A \left[f''(x,y) \right]^2 dA$$

Note that we have substituted a bivariate for the usual univariate function f. Essentially L1 measures how flat a surface is and L2, how planar. Numerical approximations to these quantities were calculated as follows:

L1: Estimate slope at every cell, square, find the average over the map.

L2: Estimate the slope of the slope, square, find the average.

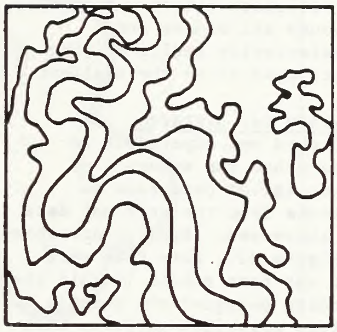


Figure 20

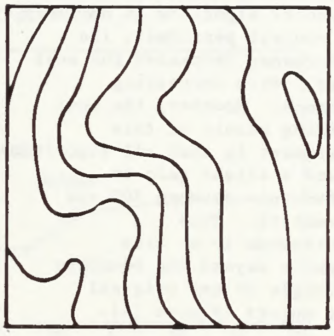


Figure 21

PRELIMINARY RESULTS

Accuracy. Table I shows the accuracy (correlation coefficients) for each of the four interpolation algorithms, using each of the six combinations of data point distribution and sample surface. The fourth row (43 points) is presented in bar graph form in Figure 22, and is typical of the relative accuracies. In general, kriging is the most accurate of the four methods, followed by a quadrant search, followed by quintic-splines, followed by inverse-distance weighting. However, the quadrant search algorithm performed almost as well as kriging. The performance of the splines algorithm was the most variable, and appeared to be highly dependent on the geometry of the point distribution. In Figure 32, the bounding polygon of the data point set is clearly by marked false "discontinuities" in the contour map. These are a result of the triangulation algorithm, which tends to form long, narrow triangles near the boundary of the data set.

Table II is a selection of interpolation biases. Note that, although all biases are satisfactorily small, kriging biases tend to be the smallest.

Accuracy vs. Distance. We performed one experiment to measure how the accuracy of interpolation decreased as distance from the original data set increased. Results are shown in Figure 23. Note that very near the data points (within the bounding polygon) the quintic splines algorithm performs much better than it does outside this area. The "weight" (inverse-distance) algorithm is not only the poorest performer, its performance decreased the most rapidly with increasing distance. However, the most striking result of this experiment is that all algorithms showed a slight gain in performance between 700 and 800 meters. This corresponds to an area slightly beyond the bounding rectangle of the original data points (Figure 24).

Robustness. Figure 25 plots interpolation accuracy of kriging against number of data points used in the calculation, for the 53 point data set, surface 3. Surprisingly, there appears to be an optimum number of points, between about 10 and 20. It is hypothesized that including too many data points in the calculation may have a flattening effect on the interpolation. This subject needs to be explored further.

Figure 26 and Tables III through V show the effects of changing the kriging parameters - sill, range of influence and nugget value. These results were obtained by repeatedly kriging from the 43 point data set, surface 2. A spherical, isotropic variogram was specified in all cases. (The three lines in Figure 26 have been vertically separated to improve readability. Only the slopes can be directly compared. The shallower the slope, the greater the robustness.)

TABLE I

CORRELATION COEFFICIENTS OF RE-INTERPOLATED SURFACES

Wolf Ridge DEM	Krig	Quad	Spline	Weight
43 pt sample	.8072	.7950	.7734	.6562
53 pt sample	.7338	.6778	.4634	.5685
365 pt sample	.9256	.9225	.9435	.9154
Morrisson Surface				
43 pt sample	.4640	.3064	.2850	.2014
53 pt sample	.3339	.2346	.1778	.2995
365 pt sample	.7864	.7353	.4917	.7082

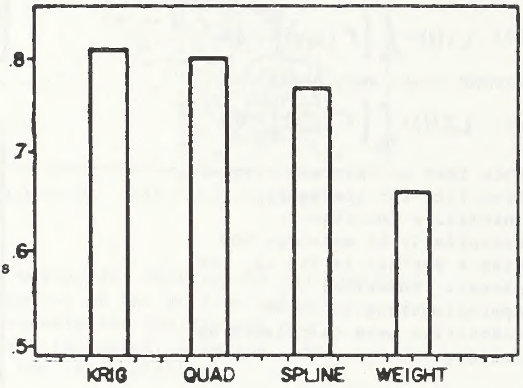


Figure 22

TABLE II. BIAS OF RE-INTERPOLATED SURFACES
(mean residual divided by range)

Wolf Ridge DEM	Krig	Quad	Spline	Weight
43 pt sample	-.009	-.008	-.094	-.014
53 pt sample	+.029	+.022	+.168	+.002
365 pt sample	-.010	-.012	-.032	-.008
Morrison Surface				
43 pt sample	+.017	+.014	+.026	+.018
53 pt sample	-.001	+.001	+.015	+.005
365 pt sample	-.005	-.004	+.007	-.003

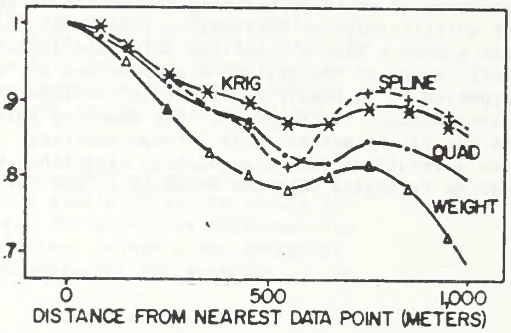


Figure 23

Perhaps the most striking result was that, regardless of the sill value entered, the accuracy of the output map remained absolutely constant. This was true even when the sill value changed by an order of magnitude or more. This can be explained by examining the mechanics of kriging. In a spherical or linear variogram, if the nugget value is zero, then a change in the sill implies that the equations (4) and (5) are multipled by a constant. Thus, in interpolating to a point, the variances of the surrounding data points are all scaled by the same factor and their relative weights remain the same.

The assumption of a zero nugget value is critical in the above paragraph. It points out an important deficiency in our study. Both of our sample surfaces had nugget values of zero. This is reasonable; in both a mathematical simulation from a continuous function and in elevation data, the difference in Z-values of two points would be expected to vanish as the two points became arbitrarily close. Kriging needs to be tested on naturally discontinuous as well as naturally continuous surfaces.

With regard to the other kriging parameters, specifying a too small range of influence will affect the accuracy greatly, but a too large range of influence will affect it very little. (This again, may be affected by the assumption of a zero nugget.) A change in nugget value appears to have a roughly linear affect on accuracy.

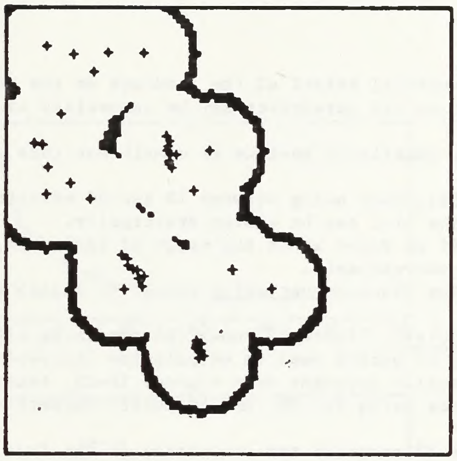


Figure 24

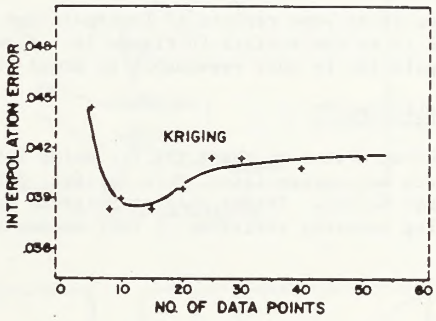


Figure 25

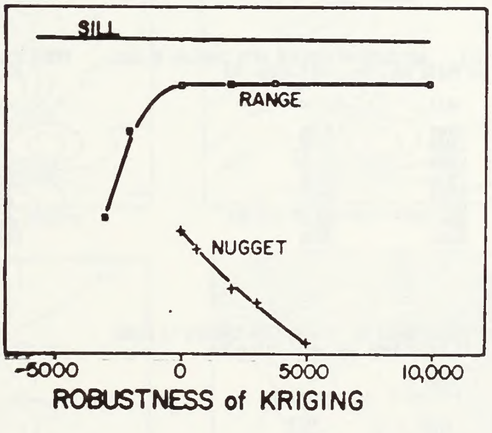


Figure 26

The practical effect of the findings on the robustness of kriging with regard to its parameters may be summarized as follows:

If the underlying surface is continuous (has a very small nugget) then:

- Calculate using between 10 and 20 nearest data points.
- The sill can be chosen arbitrarily.
- If in doubt about the range of influence, overestimate rather than underestimate.
- The exact nugget value should be chosen with care.

Smoothness. Figure 27 shows the smoothing effect in kriging as the number of points used in calculation increases. This smoothing effect is visually apparent from Figures 29-32, contour plots of kriged surfaces using 15, 30, and 50 points respectively.

Figure 28 compares the smoothness of the four methods. Splining consistently produced the least smooth output. Compare this with the visual evidence of Figure 29.

Figures 29-32 show results of interpolation from the data points in Figure 17 to the surface in Figure 14. Visual inspection shows that interpolation is only reasonable in areas close to the data points.

ACKNOWLEDGEMENTS

The author wishes to thank the following individuals for their helpful comments and suggestions: Mike Garratt, Sol Katz, Dennis Collarelli and Eric Strand. Thanks also to Margaret Mech for her patience in retyping numerous revisions of this document.

TABLE III. ACCURACY OF KRIGING WITH CHANGES IN SILL
43 Point Data Set, Wolf Ridge DEM

sill	accuracy
5000	.8070
10000	.8070
15000	.8070
19000	.8070
30000	.8070
40000	.8070
50000	.8070
80000	.8070

TABLE IV. ACCURACY OF KRIGING WITH CHANGES IN RANGE
43 Point Data Set, Wolf Ridge DEM

range of influence	accuracy
1000	.7522
2000	.7872
3000	.8070
4000	.8072
5000	.8070
6000	.8068
14000	.8064
24000	.8063

TABLE V. ACCURACY OF KRIGING WITH CHANGES IN NUGGET
43 Point Data Set, Wolf Ridge DEM

nugget	accuracy
0	.8070
500	.7999
1000	.7944
2000	.7849
3000	.7763
5000	.7600
10000	.7156
19000	.5879

Figure 27

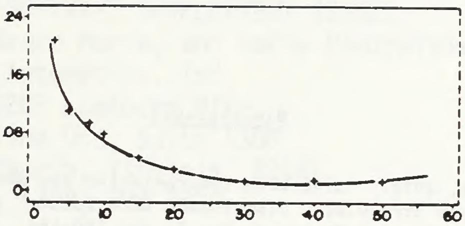


Figure 28

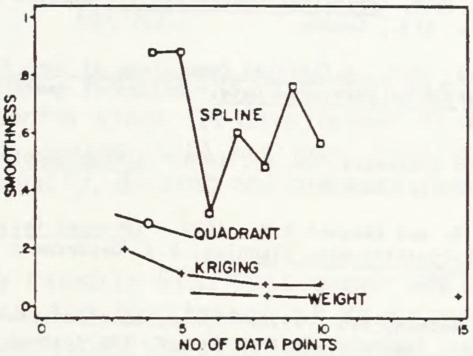
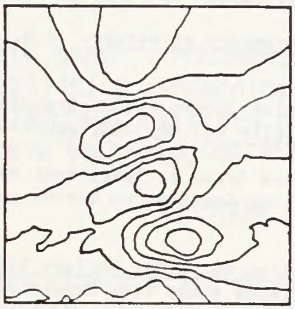
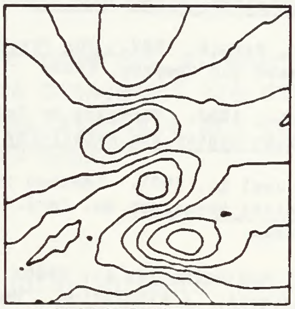


Figure 29 - Left

Figure 30 - Right



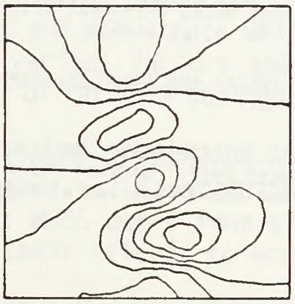
KRIGING-15 POINTS



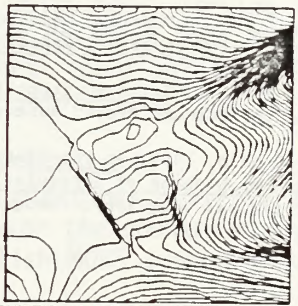
KRIGING-30 NEAREST POINTS

Figure 31 - Left

Figure 32 - Right



KRIGING-50 NEAREST POINTS



QUINTIC SPLINE-10 NEAREST POINTS

Bibliography

Akima, Hiroshi, 1978. "Bivariate Interpolation and Smooth Surface Fitting for Irregularly Distributed Data Points" ACM Transactions For Mathematical Software 4, No. 2, pp. 160-164

Clark, Isobel, 1978. Practical Geostatistics, Applied Science Publishers, Ltd., London.

Franke, Richard, 1979. A Critical Comparison of Some Methods for Interpolation of Scattered Data. Office of Naval Research, Arlington, VA.

Journel, A. and Huijregts, Ch. J., 1978. Mining Geostatistics. Academic Press, London.

Kim Y., Myers D. and Knudsen H.P., 1977. Advanced Geostatistics in Ore Reserve Estimation Mine Planning, U.S. Department of Energy, Grand Junction, CO.

Kubik, K. and Botman, A.G., 1976. "Interpolation Accuracy for Topographic and Geological Surfaces", ITC Journal 4, pp. 236-273

Lam, Nina Siu-Ngam, 1983. "Spatial Interpolation Methods, a Review". The American Cartographer 10, No. 2, pp 129-150

Mandelbrot, Benoit, 1982. The Fractal Geometry of Nature. W.H. Freemand and Company, 1982.

Matheron, G., 1967. "Kriging or Polynomial Interpolation Procedures?" Canadian Mining and Metallurgy Bulletin 60, No. 665, pp. 1041-1045.

Morrison, Joel L., 1971. "Method Produced Error in Isarithmic Mapping", Technical Monograph No. CA-5. American Congress on Survey and Mapping.

Oden, Neil and Meinhold, A., 1986. Kriging and Other Surface Estimation Techniques: A Simulation. Unpublished study from Brookhaven National Laboratories, Upton, NY.

Olea, R.A., 1974. "Optimal Contour Mapping Using Universal Kriging" Journal of Geophysical Research 79, No. 5, pp 695-702.

Pavlidis, Theo, 1982. Algorithms for Graphics and Image Processing. Computer Science Press, Rockville, MD.

Shepard, Donald, 1968. A Two-Dimensional Interpolation Function for Computer Mapping of Irregularly Spaced Data. Harvard Paper in Theoretical Geography, "Geography and the Properties of Surfaces" Series No. 5.

MOSS FAMILY SOFTWARE DEVELOPMENT ISSUES

Daniel Alberts, Bruce Morse, and Harry Niedzwiadek
Autometric, Inc.
5205 Leesburg Pike
Skyline One, Suite 1308
Falls Church, Virginia 22041
(703) 998-7606

ABSTRACT

The MOSS family of software (AMS/ADS, MOSS, MAPS, and COS) has been used by several government agencies and private companies since its development in the late 1970's. This public domain Geographic Information System (GIS) has been developed and maintained by several groups of engineers. Consequently, dataset and database formats differ across the subsystems within the GIS.

Though the MOSS family is a fully capable GIS, this paper explores several issues concerning future GIS requirements and the impact of these requirements on MOSS. Considerations such as arc/node formats, configuration management, programming languages, new data constructs, and man-machine interface, to name a few, will assure the growth and applicability of MOSS-GIS technology for years to come.

Autometric, Inc. through this paper, discusses the progress already made towards this future technology. New capabilities concerning data management are discussed. Different approaches being used to display, edit and manipulate data are explored. Finally, suggestions for achieving these technologies are addressed.

INTRODUCTION

The MOSS family of Geographic Information System (GIS) software (ADS/AMS/MOSS/MAPS/COS) has been successfully used within the public sector since the late 1970's. The use of a single package by different Federal agencies, all which have varying requirements, is a testament to the flexibility and robustness which was designed into MOSS during its early development. Nevertheless various factors and events have unfolded in recent years to raise concern on the ability of MOSS to continue to satisfy the user.

The user community is well aware of some of MOSS's limitations, as much effort has been expended to identify and suggest solutions to the limitations. This is evidenced no where better than by the fact that MOSS users from all over the country are gathered this week to cooperate and coordinate their efforts to accomplish MOSS system growth.

It is informative to briefly list and describe a few factors and events which MOSS operates under to provide a better perspective of the current functional limitations of MOSS.

1. The increased sophistication of MOSS users and uses has required MOSS to do things it was not designed to do.

2. The Federal budget allocations for GIS support have not kept pace with the increased GIS technological growth demands.

3. The various Federal agencies, due to their different mandates, require and use MOSS for a wide range of needs making it difficult to coordinate MOSS developments.

4. A number of commercial GIS packages are being marketed, creating confusion over what is needed and what is wanted.

5. The public domain nature of MOSS makes it very difficult to control and to manage the distribution and development of MOSS.

It is the purpose of this paper not to dwell on MOSS's current limitations, but rather to provide insight into some of MOSS's limitations and suggest ways in which we, the MOSS community, can resolve and implement improvements. Throughout this paper, Autometric would like to present an outline for moving MOSS into the next generation.

To assure that the next generation MOSS is on the leading edge and not the bleeding edge, we must first investigate the user requirements. Identification of these requirements are of utmost importance since they will guide MOSS development into the next generation. The user requirements can be grouped into four different categories. A brief discussion of each category will be followed by MOSS design and development considerations which will satisfy the stated user requirement.

REQUIREMENTS

Future Data Requirements.

The MOSS family was designed to handle the few data types which were deemed necessary 10 years ago. These data included spatial data (arc/node, vector, raster) and attribute data (feature subject, map descriptive information, area, etc.). As user demands for added functionality increased, enhancements to the existing software were made, such as adding more multiple attribute handling capability and analysis of elevation data. Sophisticated uses of MOSS, which require interfaces and storage of different types of data, as well as the integration of data types, have caused Autometric to investigate new data structure designs and interfaces. These new designs need to maintain the current functionality, while adding new capabilities which are compatible with the needs of the MOSS community. The next generation MOSS must be designed to accommodate future requirements, such as the data standards recently proposed by National Committee on Digital Cartographic Data Standards (NCDCDS) and/or those described by the Federal Geographic Exchange Format (FGEF).

The efforts to standardize digital data by groups like NCDCDS should be supported, but it must also be realized that there is and will continue to be large amounts of digital data in non-standard formats. MOSS must be able to accommodate these external data sources in two ways. The first is the means in which the data is brought into MOSS, preferably through a user-defined exchange format. Secondly, the data needs to be stored in new data structures which allow for extremely rapid access.

Robustness for Future Requirements.

It has already been mentioned that MOSS is being applied to projects which require higher degrees of sophistication in spatial analysis. In an increasing number of cases MOSS is being expected to perform in areas which it has never been designed to operate in. A recent example has been the addition of on-screen map editing capabilities to the MOSS subsystem using the polygon data format. Editing is very slow because the polygon structure is not conducive to real-time editing. MOSS needs to be redesigned to take advantage of an arc/node data structure, such as that found in AMS, and to take advantage of new sorting and searching techniques being prototyped by Autometric.

Quality Control and Data Integrity Requirements.

Initially MOSS was designed primarily for assisting in natural resource management. The integrity and quality of the data being analyzed was not a major consideration. Current and future uses of MOSS require that information on data integrity and quality be known and that ways to store this information in MOSS be available. Any new design of MOSS needs to provide assurance about data origin, positional and attribute accuracy, logical consistency, completeness, and currency of the data. The new data standards for digital cartographic data should be observed, such as those being proposed by NCDCDS and FICCDC.

Production Requirements.

MOSS is not a prototype GIS. It has been used in the production environment for many years. This is not to say it is not used in a research or pilot project mode. It is expected that as more groups use MOSS, it will be required more frequently to operate as a production system. This is how it is used for the National Wetland Inventory. The next generation MOSS should be designed with an emphasis toward meeting the requirements imposed by production environments, such as effective user interface, data updates, software revision, data quality and data exchange.

Design considerations need to address innovative and effective man-machine interfaces, which should include expert system technology. The interfaces must make MOSS easier, thus more efficient to use.

The quality and integrity of the data must be assured, especially in the situation where data is being shared or provided by different groups.

Configuration management issues must be considered. Further improvements for releasing updates and revisions to the user community need to be investigated to assure that groups using MOSS on a production schedule are not impacted.

Most groups using MOSS are still in the first cycle of data entry. The problems associated with updating their databases have rarely been discussed. The next generation MOSS must address this issue and provide ways to painlessly accomplish this task while maintaining a record of modifications to the database.

FUTURE SOFTWARE ENHANCEMENTS

New Data Model for Vector Data

All developers of GIS software today will attest to the importance of the system data model(s) with regard to the efficiency and robust nature of the system. Early systems, such as MOSS, offered an adequate complement of user tools, but were constrained in performance and functionality due to their data models. Recent developments have demonstrated new data models which offer dramatic improvements in system performance, and have straight-forward algorithms for certain GIS functions that were formerly difficult and/or impractical to implement. One such effort at Autometric has lead to a prototype system which will serve as the core of a new generation of GIS software. Current plans include integrating some existing GIS applications software with this prototype system. The effort is now being supported by Autometric internal research and development and two interested clients.

There are two major issues regarding the vector data models currently used in the MOSS family of software.

1. The vector data processing software packages (AMS, ADS and MOSS) each have a unique data model.

2. These data models impose certain functional constraints and are not as efficient in storage and performance as current state-of-the-art data models.

A Single Model for the System.

The main concern regarding the first issue is that there is a significant amount of duplicate functionality between the systems. We believe this to be the most important economic waste factor affecting the growth and maintenance of the system today. The formation of a more uniform system operating off a single data model would result in substantial total system life-cycle cost savings. At this time, the software which is in common or could be in common between two or more of the existing software packages consists of the following sets of functions: graphics and textual display, graphics and textual data entry/edit, analytical, math, database access, coordinate conversion, data validation, data exchange, data integrity protection, bit/byte/word manipulation, and error processing. The elimination of this duplicate functionality would result in an estimated 34% reduction in total lines of code for vector data processing.

Defining a Robust Vector Data Model.

The second issue concerning the current vector data models can be resolved by adopting a more robust data model which is designed with algorithm efficiency and storage compaction in mind. Research has shown that the best type of data model is that which is simply refered to as arc/node. This model reduces the cartographic information to a framework of points, interconnecting lines and polygons, known as topologic nodes, edges (arcs) and faces, respectively. The nodes, defined by a single spatial point, represent a cartographic point feature, the intersection of three or more edges, and/or the termination of an edge, either on itself or at an isolated point. The edges, defined by a connecting chain of line segments; represent both cartographic line features and the boundaries between adjacent cartographic area features. The faces, defined by a directed list of edges, represent entire cartographic area features or portions of area features. Defining areas in this manner eliminates the duplication of co-boundary coordinate data, such as that found in MOSS, thereby reducing storage overhead and improving system performance.

The explicit representation of the topology offers several additional advantages in data processing. First, analytical functions such as merge/dissolve and networking involve relatively simple algorithms. For example, merging polygon types A and B is solved by simply eliminating all edges which serve as a boundary between A and B and reclassifying the resultant polygons as a new type. Secondly, cartographic display functions are much more efficient, particularly for symbol conflict detection and resolution. Finally, the topology serves as the primary vehicle for determining the logical consistency of the data. For example, in the prototype system at Autometric, the full set of topology is formed as digitizing occurs making it possible to perform data verification "on-the-fly". This includes checking for edges which cross other edges.

The vector data models currently used in the MOSS family impose limitations on how cartographic features are defined. The models do not permit the definition of a cartographic feature which is composed of more than one topological node, edge or face, or some combination of two or more nodes, edges and faces. In the former case, a given cartographic point feature might consist of several individual nodes; a line feature might consist of several connecting or disjoint edges; and an area feature might consist of several connecting or disjoint faces. In the latter case, a cartographic feature might have a variety of topologic content. For example, a river may be defined by an alternating sequence of connecting faces (where the river widens) and edges (where the river narrows). Both of these representations are possible if the cartographic level of information is separated from the topological level. Furthermore, the definition of a cartographic feature can be generalized to permit cartographic features which are composed of two or more cartographic features. For example, an airport can be comprised of a terminal, service buildings, runways and taxiways. This means of representing the cartographic content, built upon the basic topologic and spatial information, offers a more accurate model of the real world. The resulting data model depicts the true character of the earth's surface by establishing a hierarchical composition scheme. In this scheme, features are comprised of other features which are comprised of topological data which are described by spatial data. This model can also handle cartographic data in an integrated form, such as those resulting from successive polygon overlay operations, where overlapping areas define new faces which belong to the contributing cartographic areas (i.e. each affected area will point to the face defining the overlap region). The data structure for this model is network in nature.

Attribute Database

One final improvement to the vector data model is to store the attribute information associated with each cartographic feature in a separate data structure, with bidirectional pointers used to tie the graphic components to the attribute information, resulting in a hybrid data model. Our detailed analysis of attribution requirements has lead us to the conclusion that the attribute database should be as follows:

The database ought consist of one or more relations (rows), which are the attributes pertaining to one or more objects. Each relation will have a user specified identifier (pointer). Each relation will contain a fixed number of ordered fields (individual attributes). The field types and order should be the same for each relation in the named database, with the exceptions noted below. The fields may be key or non-key for query purposes. Range testing is required for the numeric fields. One of the fields must contain a pointer(s) to the associated graphic component(s).

In standard form, a series of relations will compose a table. However, two exceptions are possible. It must be possible to add a list of variable-length text to a relation. This permits analysts to attach descriptive text to cartographic features, when so desired. It must also be possible to store multiple values (variable-length list, unordered) for any field. This enhancement offers a means to have an attribute relation point to several cartographic features, etc. Both of these exceptions to the standard form admit a non-normalized attribute data structure, which some Relational DBMS's are incapable of handling.

The specific sets of functions required in support of the attribute database form a lengthy list, which will be summarized here. A full complement of file/memory management and schema definition functions are required. This should include the capabilities for users to define, edit and review the schemas through interactive means. Validation criteria should be defined as the schemas are defined. Functions to allow the applications modules to satisfy all basic access requirements must include: the ability to search and retrieve entire relations or individual fields, given Boolean or relational search criteria; add or delete relations or fields values at any time; provide ownership to the relation and field level; and handle arithmatic expressions involving key attributes for analytical modelling purposes. Special input requirements include user-defined screen formats and a batch-oriented "stuff" capability to operate on pre-defined files of attribute data in formats defined during the schema definition phase. Special output requirements include user-defined report generators.

The Man Machine Interface.

Interest in the Man Machine Interface (MMI) is a rapidly growing, and the technologies extremely feasible. A few short years ago, this function was simply assigned the term "the front end". People who used computer systems were at least somewhat knowledgeable in their specific application, and although training may not have been extensive, the original system developers were usually available to answer questions. Furthermore, software systems were not very large. Today's systems may be comprised of several hundreds of thousands, if not millions, of lines of executable instruction code. Therefore, today's MMI must consider not only how it interacts with the user, but how the user perceives any intra-system communication. In many cases, this concept has already been extended to inter-system communication processes. Though often neglected in the past, MMIs may very well determine whether systems succeed or fail in the future, purely by the way the "personality" of the system is perceived by the user.

There are several design considerations that should go into the production of an effective and time-enduring MMI.

1. It should be designed and developed not only according to system requirements, but to user requirements as well. The end-user must be satisfied from the inception of the system to its final turnover. If this does not happen, the end-user may never exercise a perfectly acceptable system.

2. It should serve to reduce training costs.

3. It should be user-easy and friendly. Users will not use any systems that are hard to understand and hard to derive information from.

4. It should be user-flexible. The user may access the MMI in more than one mode. That is, an inexperienced user may want to access the system as a menu-driven system with help-prompting along the way; the semi-experienced user may want to access the same system using a command interpreter with continually updated help prompting being displayed; and the experienced user may wish to only use the command and advanced command language of the system.

5. It should streamline user interaction. Many times, end products necessitate the need to repeatedly request intermediate products. This type of user burden can be eliminated.

6. All computer generated messages and prompting should be meaning-ful and directed toward the specific user community.

7. Ergonomic considerations should be taken into the execution design. If the user is operating at one device, it may be preferable to the user to keep the interaction at that device, even if the interaction would normally occur at some other device.

There are several areas of the MMI that should be explored for future MOSS software implementation:

1. Screen formatting - software would generate uncluttered screens querying the user for information in specific formats. Likewise, information would be redisplayed in more meaningful formats, eliminating the need to duplicate information between screens, and eliminating eye strain and fatigue as well as shortening response times.

2. Icons - graphic symbology could be presented taking the guess work out of much of today's technical terminology. For example, the command associated with plotting a map might be substituted with a picture showing a pencil drawing a map. The user might graphically point to this icon and be queried for the required parameters.

3. Graphics - many times, graphics could enhance or take the place of tables. Examples would include histograms or pie charts supplementing area or frequency tables. Another would be a grid representing the status of data collection for specific geographic areas.

4. Intelligent default prompting - best-guess default answers can usually be generated for the user in query situations. These minimize the amount of overall time associated keystroke, thought, and correction.

5. Multiple windows - by displaying multiple windows, each displaying a different stage in a user's processing session (or sessions), the user can continue to be productive

– from region share common edges: diff o/d from geo
abstraction? org into classes of geos?
– Delete of an instance 2 geog ⇒ delete of geom?
Insert & delete rules
– clustered by proximity? prefetch into mem? if not in same pg ⇒ another disk access

in other areas while waiting for previous requests to finish. This leads to feelings of accomplishment and motivation.

6. Natural Standard Query Language (NSQL) - a NSQL should be developed eliminating the burdensome nature of the current query language. Prompting should be generalized enough to allow several grammatical forms producing the same request. The query language should be more meaningful and consistent with the English language.

7. User-Defineable Product and Command Builder - this capability would allow the user the ability to define specific commands or products for the system. An example would be a trafficability model in which the user defines all the parameters which must be queried for as well as the specific order for all the processing. Later the user would execute this trafficability model and the software would provide all the necessary prompting and automatically execute all its internal logic modules until the predefined product is obtained.

Spatial Clustering and Indexing

Current spatial indexing methodologies in the MOSS family are inefficient for functions which involve medium to large data sets. The so-called "fast file" capabilities in the system are not based upon a partitioning scheme with an accompanying indexing strategy that would effectively cluster data on the basis of spatial properties. They involve sequential searches of MBR lists against a specified location or MBR involved in the query. This technique will not suffice in situations where near-real time response is required, such as during a digitizing exercise in which data validity is determined "on-the-fly".

Rapid spatial indexing is possible given two conditions: (1) there is a means for generalizing the spatial disposition of the data such that the individual topologic or cartographic entities each can be referenced and (2) the spatial referencing information is partitioned in such a way as to cluster entities according to proximity. The first condition is normally possible by using an MBR description for each entity, although there are other means for representing the general spatial character of the data. The second condition requires an algorithm which performs proximity checks as spatial indexing data is formulated.

Autometric has developed a spatial clustering/indexing technique which has been implemented in the aforementioned prototype system. This technique, referred to as Range-trees, uses MBR's as a means to represent the spatial extent of both topologic and cartographic entities. An algorithm develops a tree structure for spatial indexing purposes in which the MBR for each entity entering the database is inserted at the approximate node in the tree, based upon proximity criteria. The tree grows downward from the top, with a limit placed on the number of entities at any node. The insertion algorithm "splits" the node when necessary. Entries can be deleted from the tree when the corresponding topologic or cartographic entities are deleted from the database. This technique offers a dramatic improvement in access speed over the "fast files" presently used in the system. Our research has concluded that it is better suited for digital cartographic data than other spatial indexing techniques such as B-trees, Quad-trees and banded search techniques.

New Data Exchange Capability

As the system grows and acquires new users, there is a corresponding increase in the demands for importing new data formats into the system and exporting new data formats from the system. The availability of an increasing number of new data formats is also linked to the increase in new digital map data sources. Accomodating new formats in the MOSS family of software has always been a matter of developing new custom software modules as required. The experienced developers will attest to the amount of code duplication that occurs, since the differences in exchange formats are frequently slight in basic content and format.

We are currently designing an enhancement to the software which would obviate the need to produce custom software modules for data exchange purposes. We refer to it as a data translator. The concept for the data translator is described below. There are currently several internal data structures. Each is defined by a logical/physical schema, with a data dictionary defining specific characteristics about each field in the schema. The schema definition specifies the format of each internal file which serves as a source for data being exported from the system and destination for data being imported. In general, a schema definition would exist for each basic form of internal data (i.e. vector, attribute and raster), although this is not mandatory if more formats are desired. Given these fixed internal schemas, a unique set of functions are developed to load and unload the files. These never need to be altered as long as internal formats remain unchanged. Since the external format varies, the user will be able to perform a data translation exercise by defining the specific schema of the external data set. The user will perform this operation in an interactive fashion with a set of generic formatter functions which are invoked in any order to define the detailed encoding/decoding instructions associated with the external data.

The user will have the option of reviewing and editing the schemas for external formats. Upon satisfaction, the user will save the resulting encode/decode instruction set for subsequent use. Upon invoking the data translator, the instruction sets are presented to the user as a list on the screen. In summary, custom reformatting code will become obsolete. It will be replaced by a generic set of tools available as a user-oriented system function.

Data Revision

As of now, data production efforts involving the MOSS family of software have concentrated on populating databases. Little effort has been undertaken to revise existing data from newly acquired source materials. It is only a matter of time before users of these data will want to update them. (It should be noted that new source will normally be available in the form of imagery. This makes it imperative to maintain and expand upon the photogrammetric feature extraction tools in AMS.) The demands to update data must be addressed by identifying the requirements for revision and then developing a new set of tools to facilitate the revision process. These tools should include: the ability to perform directed search techniques which will guide a user systematically through new imagery in search of changes; rapid edit tools such as a means to define an update zone which eliminates user-defined sections of the database; and the means for tracking the changes through the assignment of revision codes to the data.

SOFTWARE DEVELOPMENT CONSIDERATIONS

Software Revision

Every viable system will constantly be updated. These new releases either fix existing problems, introduce new capabilities, eliminate unnecessary functionality, and in some cases, introduce new problems. System engineers must take not only each software release into consideration for update, but also data bases created by each version of the software. Therefore, the software must have mechanisms in place that allow it to pass version information to other subsystems. These subsystems may have to be altered to act differently, based on this information. Furthermore, the data base itself should be designed to indicate which version of software caused its creation. Techniques such as these will guarantee that newer releases of software will always be able to utilize legacy data sets. An added advantage is that corrupted data can also be traced to particular software release.

Expert System Technology

Expert System Technology will be incorporated into the GIS of the future. These rule-based systems will support:

1. Automation of geographic analysis procedures

2. Feature extraction

3. Data integration and merge

4. Data validation (i.e., topological, cartographic "on-the-fly")

5. Product generation (i.e., different symbology at different map resolution, prevention of overlapping labels, etc.)

Quality Assurances.

The MOSS family of software has many built-in assurances concerning data quality and integrity. A few examples are:

1. Maps being digitized cannot be stored in the permanent data base until they have undergone an automated topological verification procedure.

2. Maps being digitized can be reprojected to any of the 21 projections and 20 ellipsoids supported by the USGS General Cartographic Transformation Package (GCTP) to obtain hardcopy plots and overlay on supporting material.

3. Map data can be reprojected to any of the 21 projections and 20 ellipsoids supported by the GCTP to enhance calculations concerning area, length, perimeter, etc.

4. Data completeness checks will be automatically performed, identifying and resolving invalid or ill-defined features.

5. Maps that were undergoing significant data change when a hardware, operating system, or program failure was encountered may be flagged as useless. The MOSS family of software does provide recovery techniques for these specific events.

Many more assurances guaranteeing the integrity and characteristics of the data should be provided to the geographical information systems of the future. The data bases must account for data source, resolution, lineage, etc.

Example:

Many years of data collection may have been performed over a specific area. Many types of sources with varying resolutions were used to gather this data. Under a given set of circumstances, a product is being produced in which there is some question about the validity of the data. If the database does not describe the characteristics of the source data, it may be impossible to make an accurate decision. In fact, the data may have to be discarded as inadequate.

Configuration Management.

The goal of configuration management is to provide a methodical approach to effect system development, enhancement, and maintenance activities, either by user requirement or technological advance, and to assure that the final product is completely upwards compatible with the original system definition. Even the most rudimentary software programs require some degree of configuration management. Small programs maintained by single programmers and operated by a small audience require the programmer to be selfmonitoring. Larger systems, maintained by a software team, targeted to larger audiences require management within the software team as well as coordination with the user group. Very large systems, maintained by teams of software engineers, exercised by many groups of users, perhaps in different geographical areas, require even more configuration management controls. In the latter case, the individual software engineers may never talk across groups or to the user communities, as is true with the user communities themselves. These examples must be under the strict control of configuration management procedures which govern the activities of each software engineering group. Obviously, as system software becomes more complex and larger, and as numbers of users of systems increases, the issue of configuration management becomes increasingly important.

Configuration management for the MOSS family of software is a complex issue. It is being enhanced and maintained by several different contractors across the nation. Furthermore, it is being used by several independent and autonomous groups. It is not uncommon to hear of one version operating in one environment and having capabilities that were never considered possible at another location. Unfortunately, however, these versions usually differ in more ways than just functionality. Their data constructs may be entirely different rendering data transfer impossible. Coding and documentation guidelines may be non-existent, forcing the differing capability to remain forever isolated.

The key requirements for configuration management as it pertains to the MOSS family of software is to 1) rigidly control modifications to software to guarantee quality and usability by all interested groups; 2) provide usable and up-to-date documentation as it pertains to the user, the programmer, and system management and quality control; and 3) provide a mechanism for consultation with all interested parties. The key issues for configuration management are policy creation, policy enforcement, and inter-group communication.

The entire MOSS family of software is a proven product. It has been in production use since the late 1970's. However, careful thought should be given to setting up a Configuration Management Board (CMB). The CMB ideally involves all parties interested in seeing these software products continue to grow. It should devise specific guidelines stating exactly how enhancements and modifications to system software will occur, how they will be monitored for definition consistency, how the implementation will proceed, and how the dissemination of the software will occur.

These goals, when reached, will not only assure a more uniform product, but a product that the community has confidence in.

Different Languages.

Today, the average computer scientist is versed with a variety of computer languages. There are many factors that must be taken into account about a programming project before a particular language is decided upon. These factors consist of: existing hardware, future hardware, types of computations, number of system users, experience of the programming staff, operating system constraints, etc. It should be remembered, that as of today, no single language is capable of solving all programming tasks with the most efficiency, considering both production and execution related costs.

A language should be selected based on the requirements of the system as well as other parts of the system. Usually, it is most desirable to have complete CPCIs written entirely in one language. Individual programming teams of engineers usually maintain individual CPCIs, and the use of single languages will keep development and maintenance costs down. Now and then, applications will be candidates for a careful mixture of two or more languages.

Consider a system that is extremely computationally intensive, yet also requires a great amount of disk access. Ninety percent of the system may be written in a language capable of efficient computation processing, such as FORTRAN, but may be composed of C or low level ASSEMBLY to handle device access. There may be other requirements for efficiency dealing with bit access and manipulation, graphics, and system services. If these specific requirements are isolated to a primitive level, or some other modular concept, maintenance costs can be minimized while maximizing efficiency.

Existing systems should not be converted to newer languages merely for the purpose of using a newer fashionable computer language. If MOSS were converted to another language, MOSS would still be MOSS as far as the user is concerned. The functionality would be identical. The system might execute slower in some areas, and faster in others. Yet, if MOSS were re-designed to use another internal data storage format, such as the prototype described earlier, then coding development could proceed with MOSS using the best suited language. The intent in this case is to provide a much better MOSS system, regardless of language.

SUMMARY OF PROGRESS

The enhancements and the design and development considerations mentioned above are but a few of the many issues that GIS specialists will face in the future. We at Autometric, have already begun addressing these issues. While most are still in the "brainstorming" phase, we have also made concrete progress with implementations with our in-house systems. The following list summarizes our in-house work:

1. The development of a prototype system designed around a new, robust vector data model with rapid spatial indexing, data verification "on-the-fly" as digitizing occurs, and new display and edit tools. The new data model permits all overlays to be folded into an integrated database. The intent is to have this data model used in place of the models in AMS and MOSS.

2. New algorithms for overlay, buffer zone generation and weed are currently being developed.

3. Detailed requirements analysis completed for a new attribute database resulting in a specification of the interface for AMS and MOSS.

4. Design is underway for a new data translator, man-machine interface and networking function.

5. Code conversion and development is undergoing a more rigid quality control program than ever before. The baseline version will continue to be supported in different operating system environments.

6. The raster processing technology will be able to define cells of any bit length.

7. Specialized data reduction and storage techniques now enable us to store and manipulate 12-16 significant digit accuracy in 32 bits. This cuts the mass storage requirements and prepares us for the accuracy that future input devices will provide.

8. Screen-based digitizing editors have been provided. This capability will promote the independent workstation concept for offices without digitizers.

9. A user-defineable workstation concept has been provided that allows users, at routine, to designate which input and output devices they wish to use.

10. A production-oriented link has been established between an image processing system and AMS. Effectively, this link allows the user to extract or evaluate information from hard or softcopy material. Image processing also facilitates change detection requirements and the image processing system makes full use of the AMS arc/node data base management system. This will support many of the forms of sensor data available today.

11. Digital Elevation Model data collection has been enhanced. The user can designate different point density intervals for the profiling process (automatically available using the APPS-IV). This has several advantages:

- Data storage requirements for flat terrain is minimized.
- Collection time for the models is minimized.
- Post-processing techniques are facilitated.
- Data extraction and manipulation is more cost effective

THE NEED FOR CONTINUED COMMUNITY COMMUNICATIONS

The most critical question at this point is - "How do we make the next generation MOSS a reality?" From Autometric's perspective, it is felt that the problems associated with making this happen are not of a technical, but rather of a management nature.

Many of the ideas that have just been discussed have been designed and prototyped at Autometric's Falls Church, Virginia office.

The management issue is more of a problem because a number of events must take place.

1. The MOSS community must believe that there is a need for a new generation MOSS, as well as support the effort.

2. There has to be minimal disruption to the community during the phasing in of the new MOSS.

3. Careful considerations of all user requirements must be undertaken with the final design of MOSS accommodating most of these needs.

4. Sources of funding must be identified.

Already there are groups and individuals who are moving toward solving these management issues. If a new MOSS is to become a reality then we must continue to support not only these efforts but also to support MOSS.

It is our belief that current technology trends and standardization efforts serve as indicators of the impending obsolescence of the present-day software. A cooperative (government and industry) Phase II enhancement effort that takes advantage of outside R&D efforts and is controlled by a new standard for software configuration management is required to meet future demands for public domain GIS software.

This paper has addressed the first step toward Phase II by identifying the driving requirements and Phase II enhancements. The next critical step is to produce a development plan which identifies specific tasking, schedule and funding requirements. This plan should consist of a gradual development effort which matches a realistic funding profile (i.e. one which reflects the limited, sometimes volatile nature of software development funds). Tasks must be carefully determined to represent clear progress towards the initial design goals, while producing immediate results for production use, with limited task interdependence. Proper software configuration management controls need to be enforced throughout the development in order to reduce total life cycle costs and properly support the expanding user base. The Phase II development plan should include specifics about standards and methodology for managing the enhancements to (maintenance of) the software.

THE MOSS FAMILY IN THE VAX ENVIRONMENT

John W. Myers, William D. McFarland and Terry W. Barney
Geographic Resources Center
University of Missouri-Columbia
235 Electrical Engineering Building
Columbia, MO 65211

ABSTRACT

The implementation of MOSS/AMS/ADDWAMS software on a VAX 11/750 computer system using the VMS operating system is discussed. Emphasis is placed on the major fixes and upgrades made to produce software packages that could satisfy our application projects. In January, 1985, the Geographic Resources Center (GRC) received a revised VAX version of MOSS from the United States Geological Survey. Although this version contained fixes for a number of problems in the original release (July, 1984), many commands were still inoperable. We have made approximately 60 changes to VAX/MOSS in the internal systems, input-output systems, disfunctional commands, and new or enhanced commands. A VAX version of AMS and a Data General version of ADDWAMS were obtained from NASA/Goddard in June, 1985. AMS was made operational with relatively minor changes to the subprocess execution. The ADDWAMS package was completely rewritten for the VAX.

Introduction

This paper provides an overview of the evolution of MOSS/AMS/ADDWAMS software on a VAX 11/750 computer system at the Geographic Resources Center (GRC) University of Missouri-Columbia. The current VAX 11/750 system configuration at the GRC, running the VMS operating system, is shown in Figure 1. The primary software revisions reported here were made during the 1985 calendar year under a cooperative agreement with Missouri's Soil Conservation Service, USDA. In January, 1985, the GRC received a revised VAX version of MOSS from the National Mapping Division, USGS, EROS Data Center. Although this version contained fixes for a number of problems in the original release (July, 1984), many functions were still inoperable. A VAX version of AMS and a Data General version of ADDWAMS were obtained from NASA/Goddard in June, 1985. AMS was made operational with relatively minor changes to the subprocess execution. ADDWAMS was converted to a working VAX version. VAX/MOSS continues to be upgraded as more functions are tested in response to specific project needs. We have not yet tested all of the DG-MOSS commands that were provided in the original VAX/MOSS.

After installation of the revised version of VAX/MOSS, three basic changes were immediately implemented. First, it was imperative that VAX/MOSS be able to cross disk boundaries. This was accomplished using

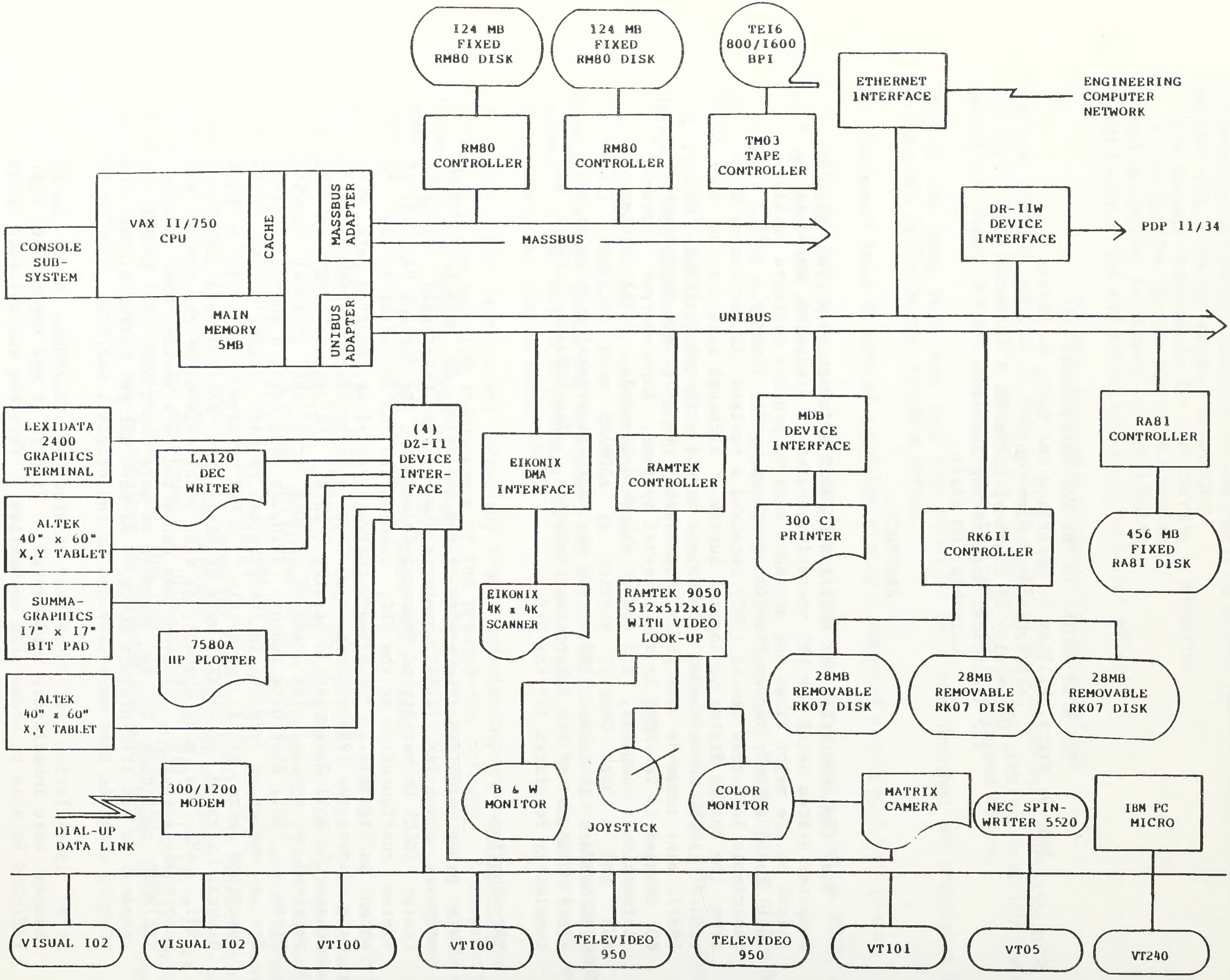


Figure 1. GRC VAX 11/750 System

a logical that defined the path to the executable code. Second, VAX/MOSS would originally leave the interactive terminal inoperable if the software made an ungraceful exit (which happened often). This required the system's manager to stop the user's process to retrieve the terminal. Changes were made to let the system control the subprocesses instead of the MOSS software. The third problem with VAX/MOSS that required immediate attention was the procedure required to add new commands. The process required modifying CTERP and rebuilding VAX/MOSS everytime a new command was added. A generic dispatcher was incorporated into VAX/MOSS to solve this problem. New commands can now be added without having to modify CTERP and rebuild.

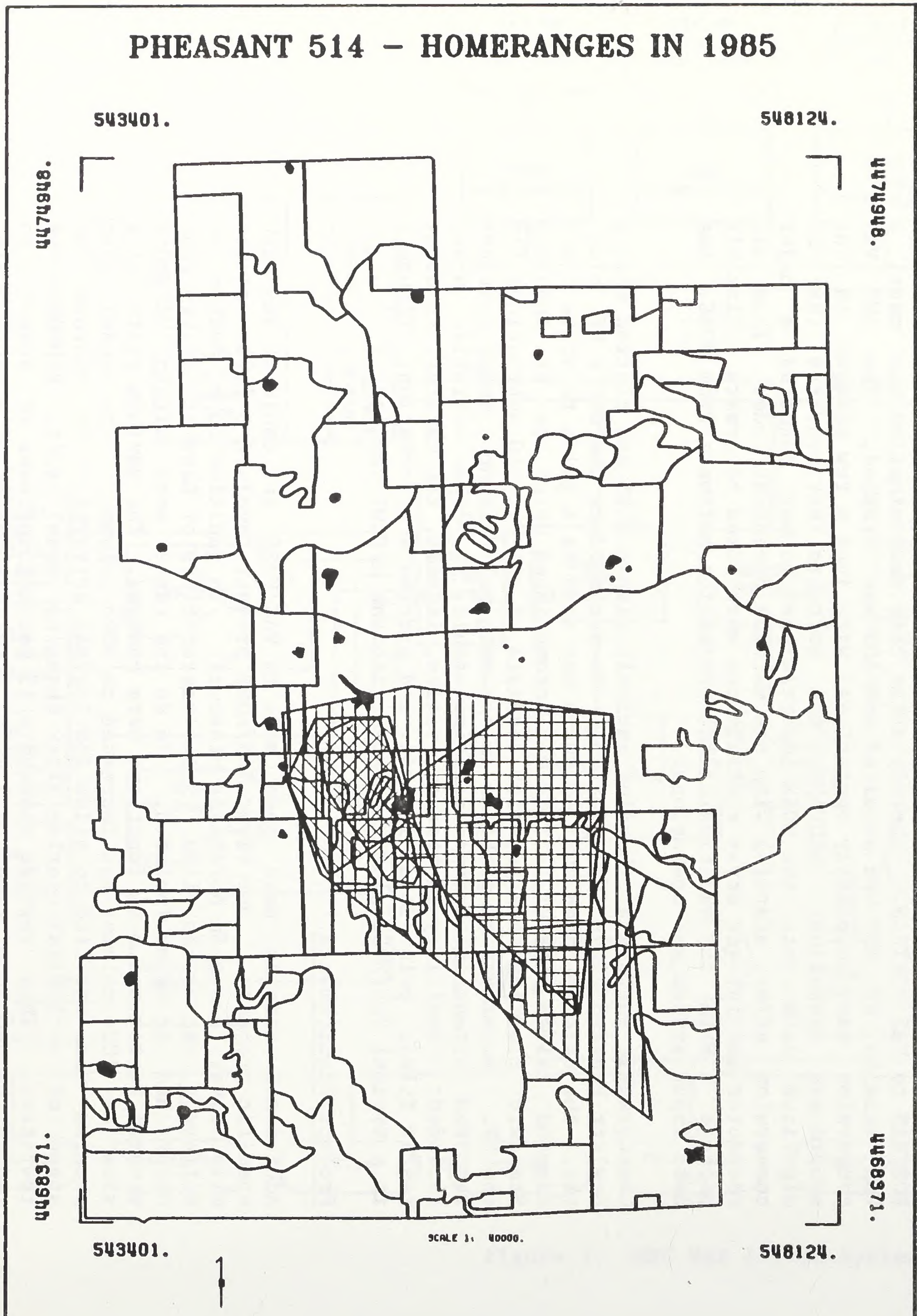
Input/Output

With these basic changes completed, attention was turned to data input and cartographic output. GRC first considered using the Bureau of Land Management's ADS digitizing software as its standard manual digitizing system. After examining the source code and looking closely at some of the system routines being utilized, it was estimated that it would require the better part of one-man-year to convert from Data General FORTRAN to VAX FORTRAN. Shortly after this determination was made, a VAX version of AMS was acquired and ADS was dropped. The AMS VAX conversion was completely operational with just a few changes to the subprocess execution. ADDWAMS, the software that converts the AMS digitized data into the MOSS import/export format required a major conversion effort starting with the machine dependent code. Then all character and integer array equivalences were fixed to create a linkable package. With the addition of the projection software from MOSS, the data input system was operational.

Cartographic outputs are handled entirely within MOSS and plotted with a Hewlett Packard 7580A (HP) plotter. To accommodate the GRC's HP plotter, the Calcomp based MOSS software was used as a guide to write a new command called HPPLOT. This was accomplished using the HP Industry Standard Plotting Package which consists of the Plot-10 subroutines for the HP. A variety of problems in the original Calcomp command software required attention before plotting could be done. Problem areas included: ancillary annotation, titles, legends, tic marking, shading, raster files, point data, islands, and attribute information. Figure 2 is a typical VAX/MOSS plot generated with the HPPLOT command.

Project Requirements

Additional changes have been made to VAX/MOSS in conjunction with specific projects. Our first VAX/MOSS project involved a 2,300 square mile river basin in Northeast Missouri. In addition to a number of different vector map files, large raster files of Landsat derived land cover had to be manipulated. To do the raster work within VAX/MOSS several raster and cell functions were changed. The maximum raster file size of 1024 columns was increased to 4096 columns. The model edit program was modified to allow 256 logical criteria. To improve the speed of a logical overlay after changing model edit, RUNMOD1 was rewritten. This rewrite yielded a 15 percent increase in speed. To reduce the amount of time required to display a subset of a raster file, VAX/MOSS was modified to read only that part of the file specified by a



MAP TYPE: PHEASANT 514 HOMERANGES DURING 1985
STUDY AREA: SCHUYLER CO. MISSOURI
PROJECT: PHEASANT TELEMETRY STUDY – MORTALITY
AND HABITAT USE SHIFTS
PREPARED FOR: MISSOURI DEPT. OF CONSERVATION
UPLAND WILDLIFE BIOLOGIST
PREPARED BY: GEOGRAPHIC RESOURCES CENTER
UNIVERSITY OF MISSOURI-COLUMBIA
UNIVERSITY EXTENSION
PHONE: 314-882-3617

MAP LEGEND

▥	HOMERANGE – 1985
▤	HOMERANGE – FEB-MARCH
▨	HOMERANGE – JUNE-JULY
▧	HOMERANGE – AUGUST-DEC
■	WATER
—	HABITAT UNIT BOUNDARIES

Figure 2. VAX/MOSS Plot
Generated with HPPLOT

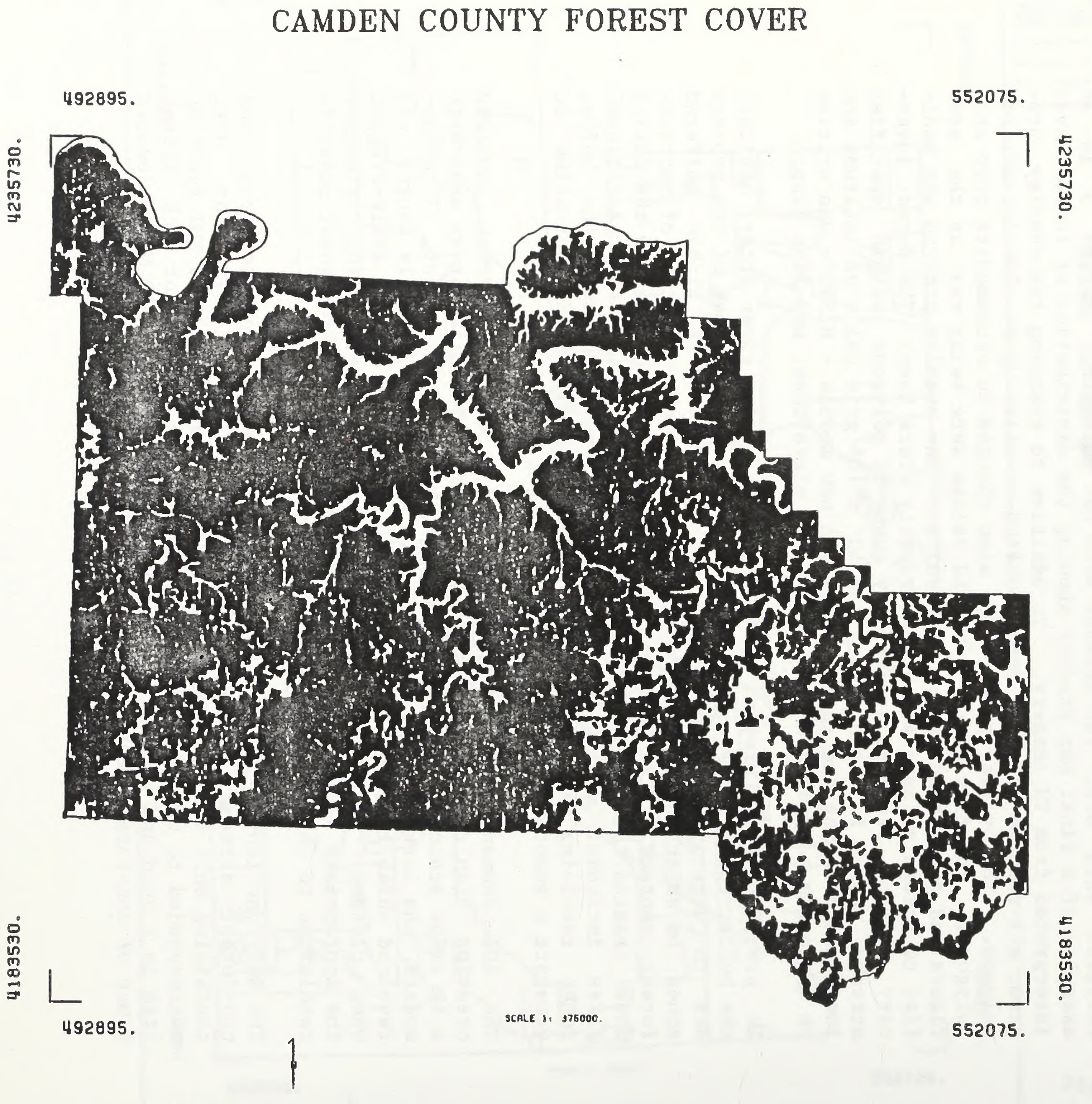
window instead of reading through the entire file ignoring the specified window.

Subsequently, several modifications to VAX/MOSS were implemented to accommodate a statewide inventory of Missouri's forest cover. Utilizing custom enlarged Landsat TM false color composite imagery, the forest cover for each of Missouri's 114 counties was manually interpreted and then digitized with AMS. Most of the problems found, involved handling a large number of islands. Initially, VAX/MOSS could only handle one island in an overlay. This was an integer*2/integer*4 buffer problem that was easily corrected. Another problem was immediately encountered that limited the number of islands stored on disk to 99. All proceeding islands were being zeroed out. SAVWRK was corrected to store the island pointers before zeroing them out. The VAX/MOSS limit of 350 islands per polygon became a serious limitation in the Ozark counties where forest cover is extensive and many small islands of non-forest cover prevail. Polygons with over 700 islands were not uncommon. Figure 3 is an example of a final map product showing the distribution of forest cover interpreted from TM imagery. In addition to changing the overlay program, all related programs were modified to allow up to 1500 islands per polygon. The overlay program was also changed to accommodate zero area polygons. In this case, centroid values were being read as the area figure and generating erroneous results. The overlay program was modified to recognize zero areas and properly store them. The forest inventory project required a frequency count of polygons within specified acreage ranges for each county and 10' x 10' grid cells of latitude and longitude covering the entire state. A new module - HISTO - was written to histogram polygon area and perimeter, elevations, and line length.

In preparing for a project involving inventorying river otter habitat, the buffer command was extensively reworked. The purpose of the project was to determine the number of acres of forest cover within buffered zones on selected streams and calculate the number of miles of stream-forest contact. The weeding function was disabled to allow the buffer zone created to more accurately surround the input data. Additional fixes included: being able to delete all the loops out of the buffer zone; resolving overlaps; and a rewrite of the VZONE subroutine to generate a smoother and more accurate buffer zone.

The ADD command was revised in support of a project that involved creating high resolution raster files of detailed soil survey maps with a 4k image scanner. The ADD command requires a scale factor. To accommodate the larger polygons in the soil maps, a large scale factor was required which in turn caused the smaller polygons to look stair-stepped when plotted. STNDRD was changed to scale each polygon and calculate the appropriate scale factor. This change allowed the highest possible resolution to be retained for each polygon.

The NOT function of the OVERLAY command was used to generate forest and non-forest acreage estimates for USGS quadrangles using data sets containing only forest polygons. To accomplish this, the NOT function was expanded to handle islands. A NOT MAP was created for each forest item in a quad and then an overlay intersection of the NOT MAPS produced a map of non-forest polygons of the quad.



MAP TITLE: 1984 FOREST LANDCOVER
LOCATION: CAMDEN COUNTY, MISSOURI
DATA SOURCE: LANDSAT TM JULY 1984
DIGITIZING INPUT: AMS
DATA BASE / GIS: VAX/MOSS
MAPPING BASE: MO. GENERAL HIGHWAY MAP
MINIMUM MAPPING SIZE: 3-5 ACRES
PREPARED FOR: MO. DEPT. OF CONSERVATION
PREPARED BY: GEOGRAPHIC RESOURCES CENTER-UMC

MAP LEGEND

- ■ FOREST
- ☐ NON-FOREST
- — CAMDEN COUNTY BORDER

Figure 3. VAX/MOSS HPPLOT
Forest Cover Map

Enhancements

Small changes, fixes, and enhancements have been worked in around project applications. After receiving Version 85.01 of the MOSS User's Manual, a number of commands were brought up to date. The exclamation point (!) and back slash (\) were added to the SELECT command. The ADD command was fixed to allow map projection information to be added to the map header and allow a map header to be built from scratch. Several simple changes were made to the hardcopy options to automatically submit files to the printer instead of the user having to exit MOSS and issuing a print command.

Color

A FLOOD command was added to VAX/MOSS to allow color display of maps on a Tektronix 4115B terminal utilizing the fill panel command of the Tektronix. The FLOOD command can display a map in color in the same time required to display unfilled polygons.

Summary

Table 1 lists some of the typical changes that have been made to VAX/MOSS to date. These modifications have been made to provide GRC with a working GIS in an efficient manner. Our current management scheme requires us to use VAX/MOSS for active projects, making modifications as necessary to support the projects and produce the required products. No attempt has been made to improve on any design philosophy or any basic structures of MOSS. Whereas, the results have been very satisfactory and the applications successful, this philosophy of patching the leaks is certainly less than optimum. Many applications would be enhanced by a merge/dissolve function to allow modular development of projects with the ability to properly combine maps. This function is not easily "patched" in. An arc-node data structure is highly desirable. This "modification" is so significant a change that a computer redesign would be more appropriate. We are not able to make that committment to VAX/MOSS at this time.

The VAX/MOSS package has served well as an available, powerful, and relatively comprehensible GIS for the time and effort we have invested. We use it for point, line, polygon, and raster processing of all digitized map files including Landsat classified image maps. We are pleased with the production of products we have been able to achieve with this public domain software. Unfortunately, we cannot conclude that we should continue to invest in the modification process knowing the severe limitations of a data structure that does not support line segments.

TABLE 1: SUMMARY OF PRIMARY MODIFICATIONS TO VAX/MOSS

Command/Module	Problem	Modification
MOSS	Crossing disk boundaries	VMS logical
MOSS	Loss of terminal	Subprocess creation
MOSS	Adding new commands	Generic dispatcher
HPPLOT	Cartographic output	New module
CANNOT	Ancillary annotation	User friendly
SCL	Scale of maps	Linear scale
TICS	Missing	Added
PLOTP	Plotter shading	Data format
PPLOT, CLLBRD	Raster limitation	4096 limit
RSTPLT,CLLBRD	Over processing	Use window
COMPOSITE	Criteria limit	Increased to 256
RUNMOD1	Slow	15% speed increase
RSTPLT,CLLBRD	Plotting cell data	Minimum plotting size
PLOTP	Plotting point date	Use middle of character as center point
PLOTP	Plotting polygon data	Island format
PISL	Island overlay	Integer *2, integer *4 array
TABARA	1500 subject limit	Increase to 3000
SAVWRK	Island overlay	Store before zeroing
POVRLY,POSL,PISL	Island overlay	Island limit
CENTAR	Bogus area	Zero area
HPPLOT	Size of plot	90 degree rotation
FNDSUB	Incorrect sorter	Byte checking
MOSS	Island limitations	Increase to 1500
HISTO	No range statistics	New command
MATCH	Selecting multiple subjects	! option added
SEARCH	Selecting items	\ option added
ADD,BACKUP	Template from scratch	Carriage return input
TABARA,HISTO,AUDIT	Hardcopy output	System submitted print files
BTEMPLT	Projection information	Stored in header
PLOTP,PLOTDV	Plotting outside neat line	Neat line window imposed
BUFFER	Vertical lines	End point processing
BUFFER	Loops	Check and eliminate
BUFFER	Crashing	User limits
STNDRD	Data resolution	Floating scale factor
VZONE	Erratic zone boundary	New algorithm
FIGURE,POVERLY	Islands in NOT OVERLAY	Islands are valid polygons
SCHOV,PLOTP,PLOTA	Attribute and item number plotting	Multiple versions
EXPORT	Large polygons	Check on vertices counter
FLOOD	Not working	Color plotting Tektronix 4115B

THE TERRAIN ANALYST WORK STATION

Elizabeth D. Porter and G. Michael Hardaway and Richard B. Marth
U.S. Army Engineer Topographic Laboratories

Commander and Director
U.S. Army Engineer Topographic Laboratories
ATTN: ETL-GS-IB
Fort Belvoir, VA 22060-5546

ABSTRACT

The Terrain Analyst Work Station (TAWS) project was initiated by the U.S. Army Engineer Topographic Laboratories (ETL) to develop a prototype system to meet the Army requirements for providing timely and accurate terrain and environmental information used in making crucial tactical decisions. The TAWS prototype will incorporate off-the-shelf hardware and will adapt existing software to provide a capability to input soft and hardcopy source information, create, enhance and maintain geographic data bases, and generate hard and softcopy terrain and environmental products. The TAWS is intended to be operated by Army terrain analysts and will be demonstrated in the laboratory and in Army field exercises.

TERRAIN ANALYSIS REQUIREMENTS

Terrain analysis is the process of analyzing military geographic information to determine the effect of the natural and man-made features on military operations. At present, terrain analysts manually assemble and analyze terrain information. These manual procedures are too cumbersome, slow, and inflexible to satisfy Army requirements for rapid generation, revision and dissemination of terrain information and terrain products. Present manual terrain analysis procedures require the analyst to collect data for the area of interest, (maps, imagery, reports, etc.), evaluate the data, (compare the data and select the most correct), prepare a thematic or factor overlay from the selected data, and if required, prepare a manuscript to accompany the factor overlay. These manual compilation process can take an experienced analyst from a week to several months to complete one factor overlay. For these reasons, manual terrain analysis is a slow, tedious process and does not meet the Army requirements for rapid product generation. To address this problem, the Army has been evaluating the utility of digital terrain data bases and automated terrain analysis systems.

Digital terrain data bases and automated terrain analysis techniques will help the Army meet the demand for quick, comprehensive terrain information. Many automated terrain analysis techniques have already been successfully demonstrated in the laboratory on an interactive computer graphics system known as the Digital Terrain Analysis Station (DTAS). Complex terrain products (cross-country movement maps and cover and concealment overlays) can be produced from prototype terrain data bases -- and can be done in a fraction of the time required by the unassisted analyst. A planned Digital Topographic

Support System (DTSS) will make such techniques available to terrain teams in the field by early 1990s.

Digital terrain analysis, however, can only become a field reality if the appropriate data bases exist to support it. The Defense Mapping Agency (DMA) has initiated efforts to supply digital topographic data to meet the needs of the military terrain analysis community. Since U.S. military commitments span the globe, it would be difficult (if not impossible) for DMA to provide the Army with digital terrain information for every area that may eventually be of strategic or tactical interest. Even if complete coverage of the earth were possible, data base users would still find gaps between these generalized digital sources and the actual lay of the land -- particularly rapidly changing feature data. Additionally, modern combat techniques can dramatically alter cultural and terrain features, making very accurate map information obsolete in a matter of minutes.

Therefore, the Army is exploring the concept of providing a supplementary computer-assisted map generating capability which can operate in both field and garrison environments. Today terrain analysts, utilizing manual map compilation techniques, have a nearly impossible task of trying to keep dynamic databases current. Even with automated tools to assist in their mission, terrain analysts will still have a task of great magnitude in updating and revising terrain data to reflect current conditions. The terrain analysts may also be required to create new terrain data bases to support military operations in areas for which DMA data are not available.

In response to this need, scientists at the Engineer Topographic Laboratories (ETL) are assembling a prototype Terrain Analyst Work Station (TAWS). The TAWS will explore a varity of techniques in digital database creation and manipulation and will demonstrate different phases of computer-assisted map compilation to the Army terrain analysis user community. TAWS is an R&D System, providing a vehicle for design proof-of-concept for testing capabilities which may be incorporated into the planned DTSS after its initial deployment.

The primary function of TAWS will be to perform data extraction, digitization, and mensuration. However, the work station will also incorporate certain data manipulation and product generation capabilities. The system will provide Army terrain analysts with the tools needed to: 1) create topologically valid digital terrain data bases using monoscopic and stereoscopic multi-sensor imagery, graphics, text, and other military geographic information data sources; 2) edit, update, revise and intensify existing data bases; 3) merge data extracted from any of the data sources; 4) overlay features on digital elevation data; 5) manipulate, analyze and display digital terrain data in 2 and 3-D views; and 6) generate and disseminate Army battlefield tactical decision aids.

TAWS PROJECT DEVELOPMENT

One of the primary objectives of the TAWS exploratory development project is to demonstrate a fieldable terrain analysis capability as quickly as possible. This required compressing the lengthy development time that is typical of fielding an operational system. Developers established a less than two year timetable from system concept formulation to the first field demonstration. Plans called for subsequent demonstrations to incorporate additional capabilities for the next three or four years as they are tested and accepted. The proposed TAWS concept called for utilizing off-the-shelf hardware and adapting and enhancing existing software to expedite the development. It seemed this would minimize costs and development time. However, it soon became evident that patching dificiencies in existing software could be a mammoth undertaking. In addition, the TAWS development effort entailed a considerable programmatic effort requiring navigation through the complex system acquisition process.

The TAWS Geographic Information System (GIS) was adapted from the MOSS family of software derived from several different systems. The software evolutionary predecessors to TAWS were written to utilize special features unique to their particular hardware configurations. Therefore, moving the software to the TAWS computer and device configuration presented a very labor intensive and time consuming effort. Because TAWS is an R&D system and will explore a variety of system configurations, the intent of the software conversion was to move away from "hard-coding" the configuration. Additional efforts were expended attempting to upgrade the documentation to a uniformly structured style to facilitate software enhancements or modifications. Some software components had never been tested under the variety of operational conditions that the TAWS might encounter. Therefore, remedial testing efforts had to be initiated as part of the project. Compounding the difficulties encountered in the software conversion effort, the TAWS project plans called for developing some new capabilities of photogrammetric source extraction, including supporting an interface to a custom-built Light Table Digitization and Mensuration System (LTMS), and creating enhanced product generation and analysis capabilities. Furthermore, because of the short development time, there was little, if any, slack time in the critical path of project activities. All programmatic and technical difficulties that resulted in activity delays had direct impacts on project completion milestones. Therefore, it was quite an achievement that the TAWS was able to meet its first demonstration commitment in October 1985 -- less than two years from project initiation.

Taws Software Development Goals

To meet the objectives of the TAWS project, a development strategy with specific goals was instituted. This strategy called for instituting modularity, portability and device independence in the software structure. The goal of modularity is intended to enable further software modifications or enhancements to be made at considerably less effort than was previously possible. It was also intended to enable the TAWS capabilities to be used either as an integrated system or as a set of independent functional components. The goal of portability is intended to enable the software to run on a variety of computers requiring only minimal changes. Portability is a good strategic goal for TAWS for two reasons: 1) it encourages potential users to get copies of the software and to increase users' exposure to digital technologies by not restricting them to using one particular computer; and 2) it makes development easier for any subsequent efforts that may occur on different computers to build upon the work accomplished under the TAWS effort. The goal of device independence is related to the goal of portability.

Often, software code is written to be used to drive a particular device. If that device is modified, or exchanged for or enhanced with a different device, a substantial portion of the code may require revision. Device independence implies that only a minimal number of routines need to be changed if the device configuration changes.

The problem of turning the code into a modular structure was tackled by segregating the software into functional groups and re-structuring the original programs. ANSI FORTRAN 77 was the primary programming language utilized to increase portability. Additionally the UNIX (trademark of Bell Laboratories) operating system was selected to host the software. UNIX is commercially available through a number of vendors and supported by most micro and minicomputer systems. To achieve device independence, a requirement was instituted to isolate all calls to specific input/output devices in libraries and to eliminate device specific graphics calls within the main applications routines. The requirements call for all applications programs to contain the ACM-Siggraph "Core" standard graphics calls.

TAWS Hardware Configuration

The TAWS microcomputer contains two 32-bit central processing units (CPUs) with six megabytes of random access memory (RAM). It is supported by 264 megabytes of winchester disk storage, 440 megabytes of removable media disk storage and a nine track, 1600 BPI tape drive. The input/output devices consist of black and white and color graphics terminals, a color graphics plotter, a color ink jet copier and rasterizer, a line printer, multiple X-Y digitizing stations, a light table digitizing and mensuration system. The system will be upgraded with an analytical stereoplotter in 1987, and may be enhanced with a scanning digitizing station in the near future. The equipment will be installed in an 8'x 8'x 20' tactical shelter over the summer 1986, to facilitate its use in Army field demonstrations.

TAWS GIS COMPONENTS

TAWS is comprised of four major components. These are: data base development (e.g., Analytical Mapping System) terrain analysis and product generation (e.g., Map Overlay and Statistical System and Map Analysis Package), intervisibility analysis and product generation, and environmental effects software. The data base development and the terrain analysis and product generation components comprise the TAWS GIS. The intervisibility analysis programs convert elevation matrices (DMA Digital Terrain Elevation Data - DTED - into specific terrain analysis products, and the environmental effects databases generate textual reports of historical, climatic, and other environmental information.

Data Base Development

The data entry component of the GIS (e.g., AMS) gives users the capability to create, update or revise digital data bases. Terrain teams can produce digital databases by manually digitizing hardcopy thematic overlays such as the Tactical Terrain Analysis Data Base (TTADB) (1:50,000 scale) and the Planning Terrain Analysis Data Base (PTADB) (1:250,000 scale) sheets. Digital data bases can also be developed from other source materials such as maps, charts, aerial photographs and textual information.

The TAWS system provides three basic instruments for data entry. These are: an X-Y digitizing table, a light table mensuration system (LTMS), and eventually an analytical stereo plotter (ASP), and map scanner subsystem. Long range plans call for interfacing the TAWS to a digital image processing subsystem.

The AMS photogrammetric routines enable the analyst to interactively compute the camera and control point parameters of selected imagery or to perform "rubber sheeting" set-up of monoscopic or stereoscopic images. The digitizing routines enable the analyst to digitize from any of the data entry devices (e.g. X-Y digitizing table, LTMS, ASP). The analyst can digitize in any scale or orientation, create a database in one of twenty map projections and then transform the data to another one of the map projections for analysis, and specify the size of the coverage for the data base. AMS also permits multiple factor overlays to be digitized for each project.

The AMS digitizing operation is interactive. The operator views the displayed results in near-real-time on a graphics terminal. The data is digitized in point mode into an arc-node formatted database. The primary left, center and right attribute information is entered at the time of digitization. Currently, no capabilities exist for entering multiple attributes in the database development subsystem. Also, the method for attribute tagging is viewed as overly cumbersome. Furthermore, the hierarchical database structure of AMS does not permit efficient edge matching of adjacent project areas. These have been recognized as important capabilities for terrain analysis applications and are planned as enhancements to the AMS software.

Once digitization is completed (actual features are formed from the arc-node spatial coordinate data and tagged attribute data), each feature in a manuscript can be topologically verified. The AMS verification routines check for various errors such as illegal or missing attributes, duplicate or kinked arcs, and slivers and gaps. Editing of arcs, nodes or attributes can be made either at the time of data entry or at a later time by querying the database for a specific arc, node or polygon. When completed successfully, the verification routines confirm that a topologically valid manuscript has been compiled. Once this process is completed, the data can be stored directly in the data base where it is immediately available for export to MOSS.

The menu-driven AMS software is regarded to be fairly "user friendly" by laboratory personnel, although the tediousness of the digitization process significantly detracts from its potential use. GIS enhancements slated for the next two or three years should evaluate the cost-benefits of implementing several significant changes to AMS or its follow on system.

Terrain Analysis and Product Generation

MOSS and MAPS comprise the terrain analysis and product generation component of the GIS. MOSS is used by TAWS to analyze the thematic overlays, perform polygonal manipulations and to "tailor" products to the terrain analyst users' needs. Typically, the analyst retrieves the digital factor maps (digitized thematic overlays) for the area in question, manipulates portions of the data, and displays or plots the resultant map product.

MOSS has a limited cartographic assignment capability, adequate for TAWS applications. However, the method of performing the cartographic assignments in MOSS needs to be through a more direct, near-real time manipulation to ensure easy learning and use. Increased speed, flexibility and reversibility are essential. The MOSS polygonal manipulation capabilities in TAWS have been exercised to their limits. ETL recognizes that a long term solution to this problem would require a major revision of MOSS involving a change in basic data structure. This enhancement will be evaluated in the near future.

TAWS uses the MOSS and MAPS GIS capabilities to generate general terrain analysis products and mobility products. The general terrain analysis products include the following: concealment, avenues of approach, key terrain and engineering material sites. The mobility products incorporate various mobility models which include the following: cross-country movement maps (for a variety of military vehicles), river crossing sites, bridge erection sites, and soil strength (trafficability) maps. Plans exist for additional models (created by other U.S. Army Corps of Engineers Laboratories) to be added to this component so additional products can be generated which will aid a commander in making tactical decisions.

The MOSS software was in very poor condition when implemented on the TAWS system. After a significant test effort, many modifications were instituted in the code. To facilitate an economical use of the limited RAM on TAWS, the MOSS commands have been separated into three groups of operations. These are: general MOSS commands, MOSS analysis commands, and MOSS utility commands. General MOSS commands are responsible for program control and map data storage and description. MOSS analysis commands are responsible for extraction and production of information from existing map data, usually resulting in a new map. MOSS utility commands are responsible for general housekeeping and display of map files. The reason the MOSS command groups are divided this way is to accomodate virtual memory limitations encountered particular to the TAWS computer and to support computer process swapping.

The MAPS software, after only a few months of sporatic testing, appears to also contain some very serious deficiencies. Most importantly, the new capability of merging DMA DTED with thematic feature data operates far below required standards, even for an R&D demonstration system. Remedial efforts have been initiated to improve the handling of DTED in MAPS. Also, ETL is examining the possiblity of enhancing MAPS with a to-be-developed public domain raster-to-vector conversion capability. This capability will be able to convert dichotomous, discrete and continuous cell values, will have editing and structuring capabilities, and can be put through a smoothing operation if needed.

MOSS and MAPS (as they now exist) do not fit into the long-term requirements for TAWS. The intent of the TAWS GIS development effort is to create integrated data entry and analysis subsystems that can handle arc-node or grid formatted data. It is the hope of ETL scientists and engineers to elicit support from the MOSS user community to assist in these siginificant changes to the GIS.

TECHNOLOGY ASSESSMENT

In October of 1985, the TAWS was taken out of the laboratory environment to the field for a first of many planned demonstrations. The first demonstration took place in a garrison at the 1st Armored Division (1AD) in Ansbach, Germany. This demonstration was a combination of a capabilities and a production demonstration, showing the 1AD how to generate intervisibility products for their area of interest. Limited AMS and MOSS capabilities were also demonstrated.

The second demonstration was in support of a field exercise with the 18th Airborne Division in Fort Bragg, North Carolina, in February, 1986. Despite having only a few months to prepare a limited area database on AMS, the resulting MOSS products generated during the exercise were very well received.

The third demonstration was a garrison demo at Fort Shafter, Hawaii, in May, 1986 for the 29th Eng BN. This demo was the first to train terrain units in digital data base generation using photo source.

The demonstrations provide three main benefits. First, ETL researchers gain valuable feedback from field users concerning the system's ease of use, the effectiveness and accuracies of tecniques and methodologies employed in the software, and the usefulness of the wide variety of products generated on TAWS. Secondly, the field units obtain a large number of terrain analysis overlays for use in their planning operations. Hundreds of unique overlays and intervisibility products have been produced during the demonstrations. Lastly, Army terrain analysts receive an introduction to the type of automated mapping system that they will be using when the Digital Topographic Support System is fielded.

During each demonstration, the trainees were given a comprehensive questionaire and were interviewed about the TAWS system performance. The general response from the trainees has been very positive; they believe a TAWS-like capability would be a welcome tool for the Army terrain units. All trainees expressed that an enhanced TAWS would enable them to perform their jobs faster and improve their overall job performance. They were also pleased to see that many of the tedious and repetitious operations that they perform manually can be done by the TAWS system. Regarding the usefulness of the products generated by TAWS, many of the terrain analysts received positive feedback from their commanders, commenting that the products are useful and assisted them in attaining their mission. The terrain analysts especially liked the flexibility the GIS offered which enabled them to tailor products to their specific needs.

In terms of adjusting to computer-assisted terrain analysis, several trainees had mixed emotions (most trainees had limited or no computer experience). Some of the trainees caught on quickly while others had considerable difficulty. The trainees had very little difficulty adapting to the menu-driven components (database development, intervisibility analysis, BEES), and reported that these subsystems were very "user friendly". The command-driven MOSS component, on the other hand, did cause the trainees some difficulty. The overall feeling for the MOSS component was that it depended too much on the user's memory and was not very "user friendly". To a certain degree, this was expected because the analysts were only given one week to learn to use the system and one or two weeks to exercise the system's capabilities.

Upcoming demonstration plans include a field exercise in the fall, 1986, at Fort Lewis, Washington in the shelter environment and another shelter-based demonstration in Korea in early 1987. Feedback received on the demonstrations will be incorporated into design changes and system enhancements which will be ongoing through the end of the decade.

RECENT ENHANCEMENTS TO THE GRID COMMAND

George W. Heine
Bureau of Land Management
Bldg. 50, DFC, P.O. Box 25047
Denver, Colorado 80225-0047

ABSTRACT

There will be substantial changes in the GRID command in the next release of MOSS. Both the user interface and internal calculations of the WEIGHT and QUAD algorithms have been altered. The user is now allowed to specify a fault line map as a barrier to the interpolation process. Finally, two new algorithms, kriging and quintic splines, will be available. All of these changes are described with particular emphasis on the new algorithms. The new VARIOGRAM command, used in connection with kriging, is also described.

During FY 85, the Branch of Technology Applications Assistance (D-443), now the Branch of GIS Implementation (D-155), at the BLM Service Center (SC), asked the Branch of Graphics Systems Development (D-441), now the Branch of GIS Development (D-154) for some substantial enhancements in the MOSS GRID command, to make it faster, more accurate and more flexible. This paper summarizes these enhancements that will be released in the next version of MOSS (scheduled for release in September 1986).

MOSS GRID is among the small number of commands that bridges the gap between the vector and raster systems. Traditionally, it accepts a point map as input and produces a grid of cells (Figure 1). Thus, data entered in vector form can be analyzed by using all the analysis capabilities of the raster system. For example, a geologist may have coal seam thickness data for a number of bore holes (points). Using GRID, (s)he interpolates between these points to produce a raster map in which each cell contains a "guess" as to the thickness of the seam in that cell. This raster file can then be used to produce an isopach (contour) map or a 3-D display or used as input to volumetric, statistical or slope analysis.

Traditionally, the user in the GRID command has had to choose between two interpolation algorithms: an inverse weighted-distance (WEIGHT) and a quadrant search weighted distance (QUAD).

The WEIGHT algorithm assumes that the influence of a data point on a target cell is inversely proportional to its distance. Thus, each data point is assigned a weight equal to one divided by its distance from the center of the target cell. The formula for computing the Z-value at the target cell is:

$$(1) \quad Z_0 = \left(\frac{1}{d_1}\right)Z_1 + \left(\frac{1}{d_2}\right)Z_2 + \bullet\bullet\bullet + \left(\frac{1}{d_n}\right)Z_n \Big/ \left(\frac{1}{d_1} + \frac{1}{d_2} + \bullet\bullet\bullet \frac{1}{d_n}\right)$$

Where Z .... Zn are the Z-values of the data points, and d .... dn are their distances from the center of the target cell.

The QUAD algorithm was designed to deal with the "cluster problem." In Figure 2, using WEIGHT, the Z-value at the target cell would probably be more influenced by the data points P_2 through P_6 than by the point P_1, even though P_1 is much closer. In the QUAD algorithm, the map area is divided into quadrants, and only one point is selected from each quadrant, regardless of its distance from the target cell.

ENHANCEMENTS TO TRADITIONAL ALGORITHMS

Some minor changes were made to the WEIGHT and QUAD algorithms during 1985. Most of the following changes were made under contract with Autometric, Inc.

- The WEIGHT algorithm was changed so that if a data point fell within a target cell, the target cell was assigned the exact value of that data point. (If several data points fell within the cell, the target cell received the simple average of their values.) This ensured that, in a contour map produced from the grid, the contour line for a given value would pass through all the original data points for that value.

- The meaning of the "roving window" option was changed as follows: In searching for the nearest data points to a target cell, the program first looks at the target cell. If no data points lie exactly in the target cell, the program then searches the eight surrounding cells. If not enough data points are found, it then searches all the cells surrounding these. It continues searching outward in this fashion until it reaches the limits of maximum roving window that the user specified. If enough data points still have not been found, the program considers this an ungridable cell, and assigns it a default value.

- The program now gives the user an opportunity to change their minds after entering grid parameters. It also allows them to specify grid cell size in meters rather than acres, rather than being limited to acres in the previous version. (These changes were made by the author.)

- Internal modifications to the program include a larger buffer size and a binary search of neighboring grid cells. These changes are transparent to the user, but result in significantly faster processing time.

FAULT LINE OPTION

The WEIGHT algorithm was modified so that the user may now specify a line vector map as a fault line map. Fault lines are considered to be absolute discontinuities on the surface to be gridded. Thus, a data point lying on one side of a fault would not be used as input to a target cell lying on the other side. This is modified to allow a marginal effect near the end of a fault line.

NEW ALGORITHMS

A major change in the GRID command is that two new interpolation algorithms, kriging and quintic splines, are now available to the user.

These algorithms are described in detail below.

KRIGING

Kriging is named for D.G. Krige, a South African mining engineer who developed a method of "statistical ore reserve estimation" for use in the gold fields. Thus, the method has deep roots in the geology and mining communities where it is still best known. The theory behind kriging is known as "geostatistics," which is somewhat misleading since kriging is a mathematical interpolation process and can be applied to any spatial data, be it that of the archeologist, the forester, the meteorologist or the surveyor.

Kriging, like the inverse-distance and quadrant search algorithms described above, is a weighted average interpolation method. That is, it assigns a Z-value to the target cell based on the formula:

$$(2) \quad Z_0 = w_1 d_1 + w_2 d_2 + \bullet\bullet\bullet + w_n d_n / (w_1 + \bullet\bullet\bullet + w_n)$$

Where W_1 ... W_n are the weights assigned to each of the data points. In kriging, rather than assume the importance of a data point varies inversely with the distance to the target cell or with the square of the distance, users analyze the data themselves and generate a mathematical function (called a covariance function) representing the best guess as to how the influence of a data point varies with distance. The kriging program asks the user for a set of parameters that describe this function and then, at every data point, solves a set of linear equations to determine the weights W_1 ... W_n.

Kriging has several distinct advantages over other gridding methods. It has been shown to be the most accurate of any weighted average algorithm. It offers a tidy and complete solution to the problem of clustered data points: in setting up the set of linear equations to find the weight to assign to a given data point, terms representing the influence of all other data points on that data point are subtracted. In a cluster, where the data points are very close together, these negative terms will be large and, therefore, the weight of each data point in the cluster will be quite small. In a cluster of five, each data point will have about one-fifth the weight it would have had it stood alone.

Another advantage to kriging, extremely useful in economic evaluations, is that it not only interpolates to a grid of cells, it also calculates the variance at each cell in the map. Thus, a second map can be produced, showing how good the interpolation has been at each point in the study area. Moreover, from this variance map, it is a simple matter to generate "confidence level" maps (for example, a map where it is 90% probable that the coal seam in a given area exceeds a certain number of feet, or where it is 75% certain that groundwater is within 100 feet of the surface).

We have provided a more detailed explanation and a bibliography of the mechanics of kriging in "A Controlled Study of Some Two-Dimensional Interpolation Methods." This paper concentrates on kriging as it appears to the MOSS user.

The MOSS kriging program, called SS2DGRID, was synthesized by W.D. Grundy (1985) of the U.S. Geological Survey (USGS) from programs written by Knudsen and Kim (1980), Skrivan and Karlinger (1980), and Journel and Huijbregts (1978). It was written as part of the USGS STATPAC System and, internally, it still uses files written in STATPAC format. The MOSS interface essentially consists of a front-end program, to read a MOSS data file and create a STATPAC file, and a rear-end program, to convert the kriged STATPAC data back to MOSS. (Please see Figure 3.)

The main disadvantages of kriging are that it is computationally intensive and that it requires a considerable amount of user training. However, Grundy's programs as implemented in MOSS appear to be quite efficient; the 32-bit version executes faster than the WEIGHT or QUAD algorithm with the same maps, and the 16-bit version seems to be about as fast. We are attempting to minimize training time by implementing a graphics-intensive variogram that will minimize the amount of user sophistication necessary.

Another possibility would be to automate the variogram process and let the machine determine variogram parameters. This has been done successfully by some vendors of commercial kriging software.

The VARIOGRAM Command

Since pre-analysis of the data is an essential first step in kriging, a new MOSS command was set up for this purpose. The variogram program was written by W.D. Grundy of USGS. The program takes a MOSS point map, gets user input, and creates an ASCII text file with a simple graphic display of the variogram. In its present form, the user must then manually determine variogram parameters. A graphics enhancement of this program is under development. It will display the variogram as a point plot on a graphics terminal and then give the user a chance to try out various sets of parameters. A mathematical curve based on these trial parameters will be plotted over the point plot. The users repeat this process until they have a satisfactory close fit.

The steps to run kriging in MOSS are as follows:

1. Use SELECT to put the point data that is to be kriged in the active table.

2. WINDOW to the point map.

3. Use the VARIOGRAM command to create a variogram of the data.

4. Repeat Step 3 until you have a "reasonable" variogram.

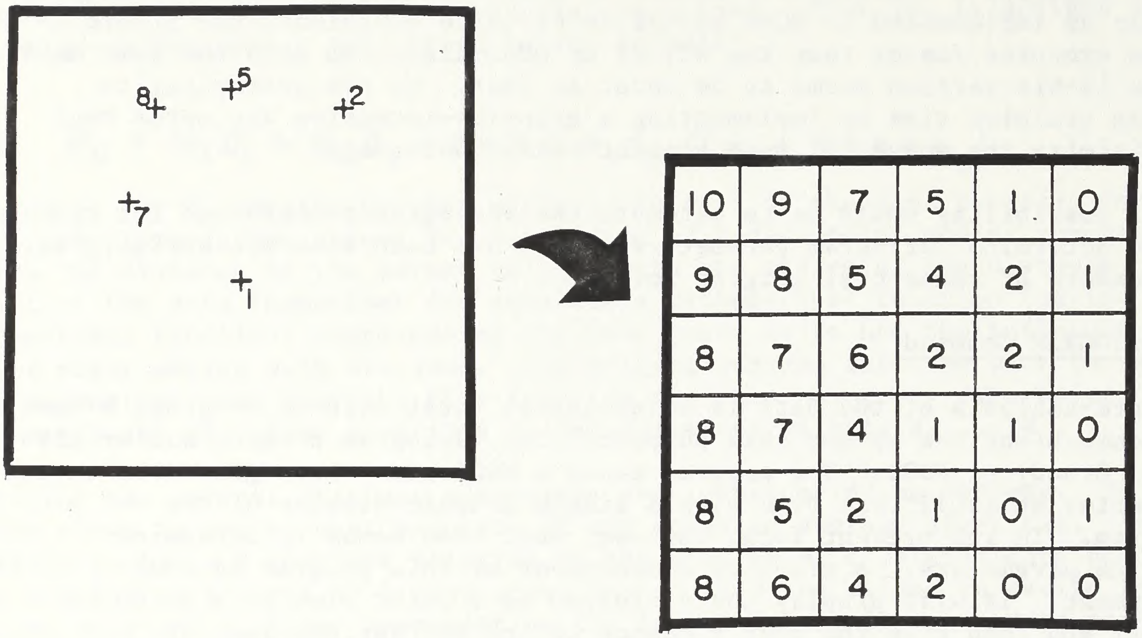
5. Use interactive graphics or manual analysis to determine variogram parameters.

6. Use the GRID command and select the KRIGING option.

7. Enter the kriging parameters in response to prompts.

Quintic Splines Algorithm

Spline interpolation methods are based on an entirely different premise than the weighted-average methods discussed so far. The area to be interpolated is first divided into triangles, where vertices are the original data points. A mathematical function is then generated over the surface, which honors all the data points and meets certain criteria of continuity and smoothness. More details on spline algorithms can be found in our paper "A Controlled Study of Some Two-Dimensional Interpolation Methods," appearing elsewhere in this volume.



10	9	7	5	1	0
9	8	5	4	2	1
8	7	6	2	2	1
8	7	4	1	1	0
8	5	2	1	0	1
8	6	4	2	0	0

Figure 1. The GRID command takes a point map (left) and interpolates to form continuous cell map (right).

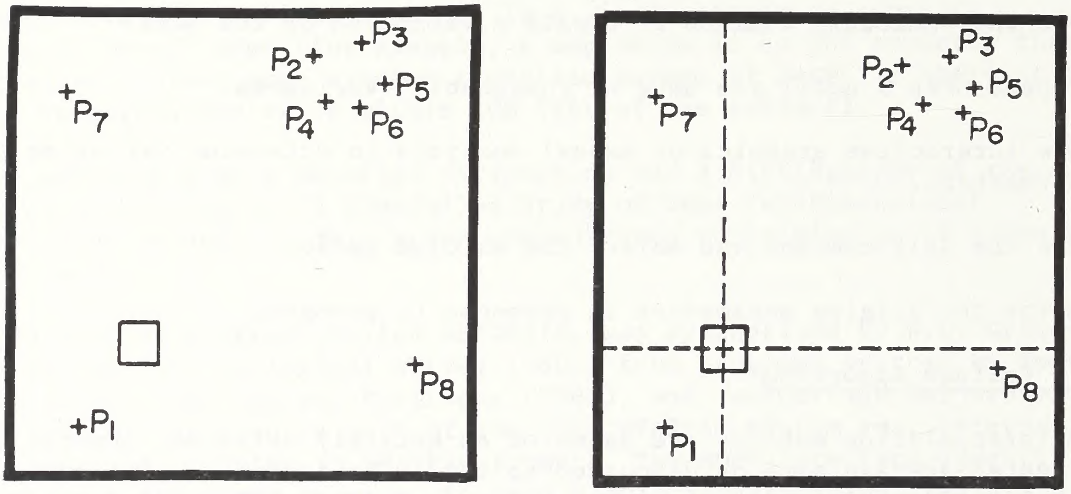


Figure 2. The cluster problem (left) and a partial solution (right) by dividing map area into quadrants.

The quintic-spline algorithm incorporated into MOSS uses the program IDSFFT, written by Hiroshi Akima (1978) and published by the Association for Computing Machinery as Algorithm number 526. The MOSS interface consists of a front-end program, to read MOSS point data and write it to binary files for processing by IDSFFT, and a rear-end program, to read the binary output of IDSFFT and write it to a MOSS contiuous cell file. (Please see Figure 5.) The only user input required by IDSFFT is the number of nearby data points to use in the interpolation.

Spline algorithms are generally quite fast, and Akima's code is especially efficient. The quintic-spline program in MOSS appears to require only about 10 to 20 percent of the processing time of the other algorithms. The accuracy, however, tends to be extremely variable. Interpolation is generally good in areas completely surrounded by data points, variable near the edge of this area, and very poor when far from data. Being based on polynomial functions, it produces a very smooth output, with pleasing contour lines. It is probably a useful algorithm for a quick trial grid when the data points are well distributed.

The quintic-spline algorithm could probably be improved with changes to its triangulation subroutine. At present, it tends to create long, narrow triangles near the bounding polygon of the data points, causing false anomalies on the grid. Another possibility is to generate cubic rather than quintic interpolation polynomials. This would create a slightly less smooth grid but more accurate extrapolation beyond the data points.

Technical Considerations

Both the variogram and kriging programs are written to be time-efficient rather than space-efficient. That is, they have brought faster processing times at the expense of large arrays, and the programs both require a great deal of stack space. Programs in the 16-bit Data General environment, however, are limited to a total space of 65K bytes. This meant that array dimensions have to be tightly limited. In the 16-bit implantation, the quintic splines program is limited to 300 input points and kriging-variogram, to 1,000 input points.

These limitations may be too restrictive for some applications and, therefore, the code for the new algorithms was slightly modified to produce a 32-bit version to run under AOS-VS. The only difference between the 16- and 32-bit implementations of these algorithms is that much larger input data sets may be used. (Current limits are 5,000 points for splines and 14,000 points for kriging, and these may be easily expanded.)

All new algorithms were written in Fortran 77, whereas most of the rest of MOSS has been written in Fortran 5. Because of this and the program size limitations described above, it was impractical to design the new algorithms as subroutines of GRID. Instead, algorithms are stand alone, swapped in processes.

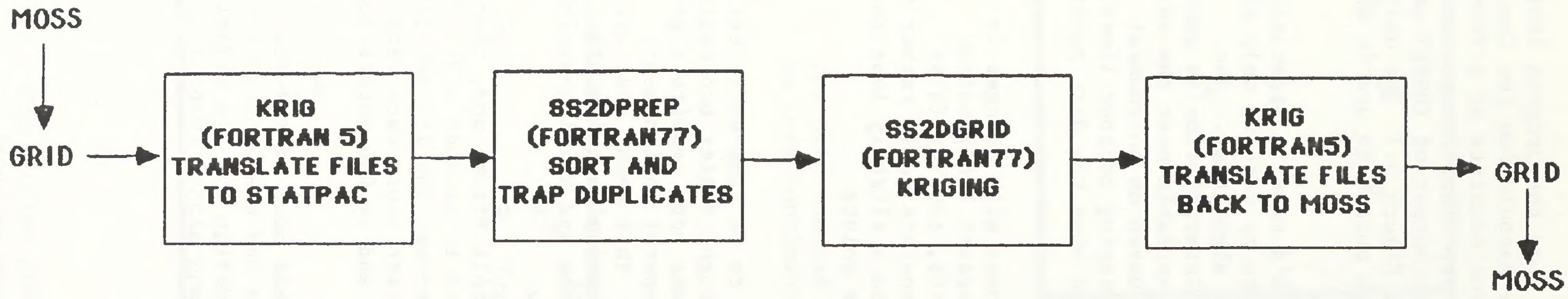

MOSS
GRID
KRIG (FORTRAN 5) TRANSLATE FILES TO STATPAC
SS2DPREP (FORTRAN77) SORT AND TRAP DUPLICATES
SS2DGRID (FORTRAN77) KRIGING
KRIG (FORTRAN5) TRANSLATE FILES BACK TO MOSS
GRID
MOSS

FIG. 3 SEQUENCE OF PROCESSING FOR KRIGING PROGRAMS

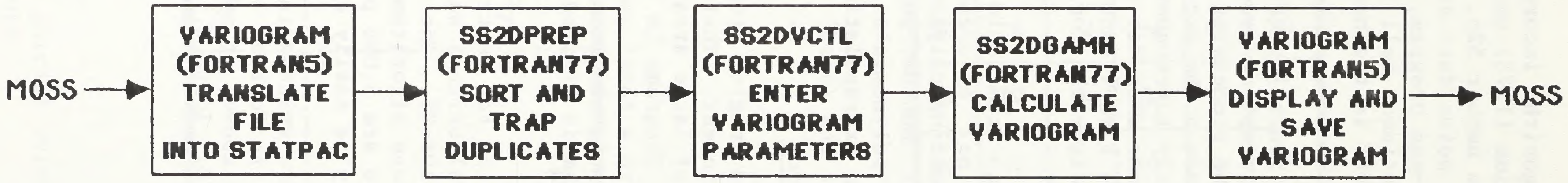

MOSS
VARIOGRAM (FORTRAN5) TRANSLATE FILE INTO STATPAC
SS2DPREP (FORTRAN77) SORT AND TRAP DUPLICATES
SS2DVCTL (FORTRAN77) ENTER VARIOGRAM PARAMETERS
SS2DGAMH (FORTRAN77) CALCULATE VARIOGRAM
VARIOGRAM (FORTRAN5) DISPLAY AND SAVE VARIOGRAM
MOSS

FIG. 4 SEQUENCE OF PROCESSING FOR VARIOGRAM PROGRAMS

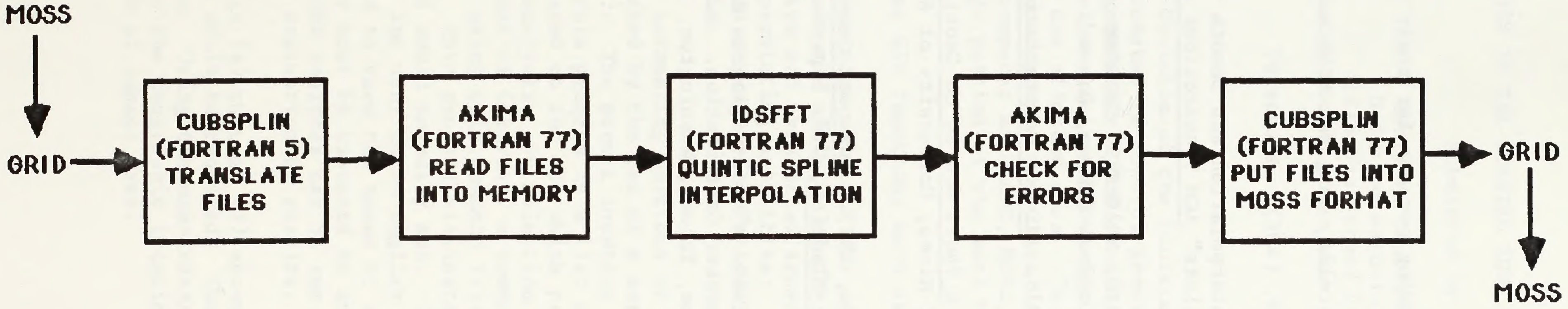

MOSS
GRID
CUBSPLIN (FORTRAN 5) TRANSLATE FILES
AKIMA (FORTRAN 77) READ FILES INTO MEMORY
IDSFFT (FORTRAN 77) QUINTIC SPLINE INTERPOLATION
AKIMA (FORTRAN 77) CHECK FOR ERRORS
CUBSPLIN (FORTRAN 77) PUT FILES INTO MOSS FORMAT
GRID
MOSS

FIG. 5 SEQUENCE OF PROCESSING FOR QUINTIC-SPLINES PROGRAMS

Acknowlegements

The author wishes to thank the following persons for their assistance in preparing this paper:

Sol Katz, George Fuller, Dennis Colarelli, Margaret Mech and Jan Poorman.

Bibliography

Akima, Hiroshi, 1978. "Bivariate Interpolation and Smooth Surface Fitting for Irregularly Distributed Data Points" ACM Transactions for Mathematical Software 4, No. 2, pp. 160-164.

Grundy, W.D., 1985. Programs SS2DGRID, SS2DPREP, SS2DGAM4, SS2DVCTL, SS2DBLOK, SS2DXVAL and BASTAT. U.S. Geological Survey, Denver, Colorado.

Journel, A. and Huijbregts, Chin, 1978. Mining Geostatistics. Academic Press, London, 600 pp.

Kim, Y.C. and Knudsen, H.P., 1980. A Short Course on Geostatistical Ore Reserve Estimation. College of Mines, University of Arizona, Tucson, Arizona, 202 pp.

Kim, Y., Myers, D., and Knudsen, H.P., 1977. Advanced Geostatistics in Ore Reserve Estimation and Mine Planning, U.S. Department of Energy, Grand Junction, Colorado.

Skrivan, J.A. and Karlinger, M.R., 1980. "Semi-Variogram Estimation and Universal Kriging Program", Computer Contribution. U.S. Geological Survey, Water Resources Division, Tacoma, Washington, 98 pp.

USE OF MOSS IN THE COASTAL ZONE PERMITTING PROCESS

submitted by

Henry R. Streiffer
Decision Associates
1276 Sharynwood Drive
Baton Rouge, Louisiana 70808-6071

Telephone: (504) 769-2117

The Coastal Management Division of the Louisiana Department of Natural Resources is legally mandated to control permitting of certain activities in the Coastal Zone. Approximately 1,500 permit applications are received each year. Analysis of permits requires knowledge of the environmental and cultural conditions of the affected area. This information exists on about 2,000 maps and aerial photographs which are used by CMD analysts. CMD has a Data General MV/10000 computer with AMS, MOSS, ERDAS and FORTRAN software systems on which a large portion of the maps have been computerized and are available to MOSS.

Permit analysis requires GIS functions such as . . .

(a) identification of the maps on which the permit site occurs;
(b) proximity searches in the vicinity of the site;
(c) location of sensitive and prohibited areas relative to the site;
(d) location of other permitting activities;
(e) change detection and acreage calculations;
(f) statistical analysis.

Decision Associates is automating portions of the CMD permitting process. This is being accomplished by the use of a map-indexing program and a MOSS Command Interface (MCI). The permit location is given to the map-index program. Output from this program is a list of all hardcopy maps. This information is then passed to the MCI which presents a menu of standard CMD procedures for permit analysis. On selection of one of these choices and the input of the areal extent of interest, a command file is created and MOSS is automatically executed using this command file. No direct user interaction with MOSS is required. This process eliminates approximately 90 percent of the questions that MOSS would normally ask. Those question that are asked by MCI can be tailored to the user in an English sentence style. The user is, therefore, not required to know the names or syntax of the MOSS commands nor the order in which they must be executed to accomplish the analysis they need. Thus, routine MOSS analyses can be run by a technician, thereby freeing the permit analyst for evaluation of results.

As an example, to obtain (a) through (f) above for a radial proximity search, about 60 MOSS commands would be required. These commands require over 50 responses for arguments. Using the map-index/MCI system, these 100 responses are generated from only the geographic location of the permit, the type of analysis and the radius of impact area.

Poster Presentations

(abstracts)

A COMPARISON OF GRAPHIC OUTPUT FOR MOSS:
COS3 vs MOSS

Larry Bagwell and Carl Zulick
TGS Technology and Bureau of Land Management
Denver Service Center

ABSTRACT

There has been considerable speculation concerning the comparison of COS and MOSS graphic output products. This poster session displays the results of applying the latest software for both systems to the same study area. An attempt was made to produce similar output for comparison. (Notes discussing the relative ease, time, and accuracy of the two systems accompany the graphics. The co-authors will be present to discuss procedures and demonstrate the systems on a Data General desk top computer.)

Conclusions of the comparison are as follows:

1. Annotation, inset, symbology, and legend flexibility and capability of COS3 exceed that of PENPLOT.
2. PENPLOT can provide a finished product faster, and is easier to use, but output format is always layed out the same, with no option to move the automatic legend from the bottom of the map.
3. Presently, COS3 and PENPLOT cannot handle cell maps.
4. Text positioning with cursor is similar in both systems. In addition, COS3 allows for text placement by xy coordinate, geographic coordinate, or interactive cursor. Nine placement justifications are possible, such as lower left, lower center, and lower right. This simplifies centering stacked lines and "hanging" text in the most appropriate locations. Moving and centering PENPLOT annotation with the text editor is difficult for new users.
5. COS3 permits the user to preview the graphics on the CRT. The user may elect to see the entire plot, individual components, or to window on certain areas.
6. PENPLOT and ANNOTATE are easier to learn. PENPLOT and ANNOTATE use decimal inches; COS3 uses centimeters with conversion capabilities to other units such as inches.
7. Both systems could benefit from enhancements. COS3 is still in development and is not available for release. Each system will provide for more output device options in future releases.

REGRESSION MODELS FOR PREDICTING AMS DIGITIZING TIMES FOR LAND RESOURCE MAPS

James R. Getter and William J. Bonner, Jr.
Department of the Interior
Bureau of Indian Affairs
1950 Constitution Avenue SW
Washington D.C. 20245

John Szajgin and Larry V. Bagwell
GeoSpatial Solutions
882 East Laurel Avenue
Boulder, Colorado 80303

ABSTRACT

The U. S. Department of the Interior, Bureau of Indian Affairs has a requirement to digitize a large number of land resource maps as part of their Geographic Information Systems development effort. The process of manual map digitizing is contracted to qualified bidders. A problem associated with this work is that estimates of digitizing time required for particular maps often vary by as much as a factor of three.

This work developed a quantitative approach to estimating the digitizing time required for land resource maps using the Analytical Mapping System (AMS). Least squares regression models suitable for use on a hand held programmable calculator were developed. These models were intended to estimate within 20% at one standard error (the 66% level) the amount of time it will take to digitize maps. Many of the models proved considerably more precise than this.

Measures of map complexity such as the number of attributes, lines segments, and polygons were used in least squares regression analysis to describe the relationships between map complexity and digitizing time. Regression models were developed for the following themes: boundaries, land cover, aerial photo centers, public land survey, range types, roads, soils, and timber. A model for all map themes was also developed. When properly applied, the resultant regression models provide an objective estimate of digitizing time. The Bureau of Indian Affairs can now conveniently develop estimates of digitizing time required for various efforts within tolerable limits of error and with a high degree of consistency. Using such an approach, individuals unfamiliar with the digitizing process can acquire some measure of the time requirement for a specified digitizing task. This facilitates more effective planning and budgeting for such efforts.

The maps used were representative of those used by the Bureau of Indian Affairs and the digitizing was performed using AMS. The effort was specific to the requirements of the Bureau of Indian Affairs,

although the resultant models are probably applicable in other organizations using AMS to digitize similar land resource maps. The concepts used and the approach taken are applicable in other organizations where there is a need to quantitatively estimate the digitizing effort required for capturing data from maps.

The use of regression analysis to gain insight into the parameters which most significantly affect manual digitizing times has proved effective. Furthermore, relatively simple models were found to be most appropriate for this purpose. The Bureau of Indian Affairs has found the implementation of these models on hand calculators very effective as a means for quantitative estimation of digitizing times by individuals who may not be familiar with the digitizing process.

APPLICATIONS OF VAX/MOSS WITH LARGE DATA SETS

by

Terry W. Barney, John W. Myers, William D. McFarland and Mary Lyon
Geographic Resources Center
University of Missouri-Columbia

This poster session will display selected results from applications of MOSS/AMS/ADDWAMS software as it has evolved in a VAX environment at the Geographic Resources Center (GRC). The displayed results will reflect a variety of applications, techniques, and study area sizes. Of special interest to the user community will be the emphasis on the exclusive use of the GIS capabilities in MOSS including the production of all cartographic output products. Three primary projects will be featured: a detailed analysis of a large hydrologic unit (Salt River Subbasin) of over 1.5 million acres, a spatial data base to assist with area land management covering approximately 12,500 acres, and a statewide forest inventory organized by county.

The Salt River study for the Soil Conservation Service utilized 61 1:24,000 USGS quadrangle sheets to input boundaries for ten watersheds. Other data inputs included general soils, Landsat land cover data as classified by the Statistical Reporting Service and point specific data from the National Resources Inventory. Two watersheds, studied in detail, contained additional data such as stream networks, detailed soils, and the 100-year floodplains. Landsat land cover data (raster) was overlayed with each of the watershed boundaries, the 100-year floodplains, the stream network and the detailed soils. General soils were also overlayed with the ten watershed boundaries.

The Missouri Department of Conservation and the GRC cooperatively devised a digital spatial data base of land use/land cover/habitat and lake level elevations covering approximately 12,500 acres at Truman Reservoir in southwest Missouri. A land use/land cover map of four management units was digitized using AMS as well as three lake level elevation boundaries. One map, showing the lake level at 726 feet, was overlayed with the land use/habitat map. The lake level map consisted of 5 polygons plus 4 islands totaling 12,279 points covering 270 miles in perimeter and 104,848 acres. The land use/management map contained 1055 polygons, 43 islands, and 43,187 points covering 782 miles in perimeter and 12,165 acres. The land use/land cover and lake level boundaries were imported into MOSS for overlay and plotting. The overlay consumed 48 hours of VAX 11/750 CPU time. Acreage estimates for all levels of land cover were calculated.

MOSS software was used to conduct a statewide inventory of Missouri's forest land cover. Over 100,000 polygons of vector forest data were interpreted on a county basis from Landsat TM imagery. Digitized using AMS, the forest polygons and county boundaries were exported to MOSS, overlayed, and plotted. The 114 county forest cover maps were merged to form a state map. The state map was overlayed with a 10 minute by 10 minute grid of latitude and longitude and proposed changes in the state's deer management unit boundaries.

During the past year, the GRC has conducted nine test applications of MOSS/AMS/ADDWAMS. If one can accept the inherent limitations imposed by the software's evolution in the public domain and has the programming capability to modify the software to its limits, MOSS is very acceptable for a variety of GIS applications.

THE APPLICATIONS OF GIS TECHNOLOGY TO WETLAND MAPPING IN DELAWARE

Robin L. Gebhard
U.S. Fish & Wildlife Service
National Wetlands Inventory
St. Petersburg, FL 33702

ABSTRACT

The U.S. Fish & Wildlife Service has, since 1975, been involved in the development and application of GIS technology to natural resource mapping and analysis. In 1982, the Service's National Wetlands Inventory (NWI) initiated a wetlands inventory in Delaware to provide state government administrators, private industry, and others with detailed information on the distribution and extent of Delaware's wetlands and deepwater habitats. The National Wetlands Inventory relies on remote sensing techniques and field investigations for wetlands identification and mapping. High altitude aerial photography ranging in scale from 1:60,000 to 1:80,000 serves as the primary remote imagery source. Once suitable high-altitude photography is obtained, there are seven major steps in preparing wetland maps: (1) field investigations, (2) photo interpretation, (3) review of existing wetland information, (4) quality assurance, (5) draft map production, (6) interagency review of draft maps, and (7) final map production. Upon publication of final wetland maps for Delaware, the Service began construction of a wetland database. This database was used to generate acreage reports on wetlands and deepwater habitats and produce detailed maps on a county basis. This project demonstrated the ability to use the Service's Analytical Mapping System (AMS), Moss Overlay and Statistical System (MOSS), and Cartographic Output System (COS) to produce highly detailed maps and databases for a statewide wetland inventory.

EXPERT SYSTEM INTERFACE WITH MOSS

William B. White and Bruce W. Morse

The authors are respectively, Impact Specialist, USDA Forest Service, Forest Pest Management/Methods Application Group, Fort Collins, Colorado; and Scientist, Autometrics, Inc., Fort Collins, Colorado.

ABSTRACT

A hazard rating conceptual model (ASPEN), allows resource managers on the Nicolet National Forest in Wisconsin to rate aspen stands for susceptibility to white trunk rot of aspen, a major decay agent.

ASPEN can be cartographically modeled utilizing various site characteristics resident in the Forest's MOSS data base to produce disease hazard rating maps. In addition, related concerns - wildlife, timber management, or any combination of the three, including disease incidence, can be addressed.

An Expert System (EXSYS) is an interactive computer program which is acting as an operating "shell" or executive program to manage a simulation model (ASPEN) and link MOSS operations. EXSYS resides on an IBM-PC/AT, while MOSS capabilities are housed in a DG-20 microcomputer.

The integration of an expert system shell to MOSS for coordinating cartographic models offers a wide range of applications in the future. Currently, additional pest simulation models are being added to the system.

GENERATING MTPS WITH ADS

by

Jeffery S. Nighbert and Michael J. Carsella
Bureau of Land Management
TGS Technology, Inc.
Santa Fe, New Mexico 87501

ABSTRACT

At the New Mexico State Office, Bureau of Land Management, the Automated Digitizing System (ADS) has proven to be an effective tool for the automation of Master Title Plats (MTP). The MTP is the Bureau's record of title and includes patent, survey, lot, lease, and other important legal land information.

In a recent GIS application involving over 150 townships in northwestern New Mexico, procedures, programs and techniques were developed for rapid generation, editing, and production of this product. Using ADS, MTPs can be produced from beginning to end in about four hours per plat, which is eight times faster than manual methods. Updates, reports and other associative processes are equally fast.

To make creation of MTPs more time and machine efficient special "generic" plat files were created, making table digitizing almost unnecessary. These files contain special linework and standard labeling for the ideal plat. Subdivision of sections are already in place down to the quarter section. Using the ADS edit program, the data entry operation simply modifies line styles of these existing lines to create the plat linework. The attribute entries such as patent number, mineral reservation and other data are made via cross-hair input on the screen.

Adding to the efficiency of pre-digitized data, several new programs were written to enhance the speed and looks of the product. The existing MODIFY command was enhanced to allow the data entry person to change the line styles of groups of lines rather than the 1 line record per command. New lettering styles and "slant" features were added to the ADS package. New plotting software was also added which allows MTPs to be produced on Zeta, HP or Calcomp plotters.

Future software enhancements to ADS software will include screen digitizing via cross-hairs, parcel generation from legal land description, and links to the Geographic Coordinate Data Base (GCDB) for portraying the correct layout of a township on the surface of the earth.

The automation of MTPs has formed an important link in the use and application of ADS/MOSS software as the central software in a land information system. This cost saving innovation will eventually lead to a comprehensive information system which can provide users with land record and resource data at their finger tips.

A MICROCOMPUTER GEOGRAPHIC INFORMATION SYSTEM WORKSTATION

Don O. Hunter
United States Fish and Wildlife Service
Western Energy and Land Use Team
Fort Collins, Colorado 80526

Geographic Information Systems (GIS's) are useful computer tools in many facets of natural resource management. The cost and complexity of computer hardware has impeded broader use of GIS's. A decade ago, GIS technology moved from mainframe computers to minicomputers. Today, GIS's are evolving around a new generation of microcomputers that allow easier, less expensive, and more remote use.

The display consists of a "typical" microcomputer GIS workstation: a computer, a graphics terminal, a plotter, and a digitizing tablet. With this complement of equipment, a GIS user is independent. Each component of the workstation is available in a variety of brands, sizes, and accessory functions. A GIS microcomputer workstation can be structured according to the specific needs of the site. For example, if the site is largely involved in map production, a pen plotter might be substituted for the copier.

This workstation consists of a Data General 10SP microcomputer configured with two 38-megabyte hard discs, a floppy disc drive, a cassette drive, and 1.0-megabyte internal memory. The graphics terminal is a Visual 500 and the copier is a Data South 180. The GIS software used in the display program is the Map Overlay and Statistical System (MOSS) developed by the U.S. Fish and Wildlife Service, Western Energy and Land Use Team. MOSS is currently being used on microcomputers by a number of Federal land management agencies including the Bureau of Land Management, Bureau of Indian Affairs, and the U.S. Forest Service.

The program running at the display shows several analysis scenarios using GIS data from the Nezperce National Forest, Idaho. Associated map products complement the self-running program.

Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the Division of Biological Services, Fish and Wildlife Service, U.S. Department of Interior.

Work Group

Summations

MANAGEMENT WORK GROUP SUMMATION

MOSS Clearing House Issue

The most important issue discussed by the management work group was the Clearing House issue, including MOSS maintenance, etc. The point was made that the whole problem must await award of the Department of the Interior (DOI) GIS computer contract, and conversion of the MOSS family software to the new machine. (During the Workshop, the award to PRIME Computers was announced.)

Several points were made in discussion:

o Still a need for research and development to meet user needs.

o Bill White called for action; the need has been discussed too long.

o Gale TeSelle suggested study of funding, staffing, management, etc., by committees, under the Steering Committee.

o Mike MacDonald said the DOI does not realize the critical need for GIS support and suggested some means of making the Department aware.

o John Singlaub suggested that Operations Work Group study funding, staffing, etc, and prepare a proposal.

o MOTION: Gale TeSelle moved to form an Operations Work Group to perform the following functions:

  - Maintain standard software
  - Newsletter and hotline
  - Monitor/report new technology
  - Build/distribute training materials
  - Conduct common training
  - Analyze cost/benefits of GIS
  - Develop college courses in GIS applied to NR management
  - Produce quality user and systems documentation
  - conduct research and development, system enhancements, etc.

. . . and that a proposal be prepared which would define the responsibilities for staffing, etc. Motion was carried.

o Denny Parker was asked to write a proposal based on CSU program, and agreed if prompt review of drafts could be obtained from Steering Committee members; group agreed.

o Claude Christensen suggested proposal be written in Interior's OIRM format for ADP procurements since it is familiar to DOI.

o It was agreed that Steering Committee members would perform reviews.

Other Business

- o It was decided that NASA and MMS be formally invited to join group. (MOTION by Claude Christensen carried.)

- o Bruce Keating asked to chair a committee to investigate where state and private organizations should be members of Cooperative Strategy. Duane Asherin volunteered to work with Bruce.

- o No one felt a need for more detailed agency role definitions.

- o MOTION: Duane Asherin moved BIA chair next Workshop, which should be held in a Front Range Colorado community . . . also that BIA make recommendations to the Steering Committee in regard to a site, dates, etc.

- o Claude Christensen reported on IDCCC activities, including new committee on GIS applications (Claude=chair); GIS Committee (Jim Getter=chair); standards work group headed now by Larry Amos. IDCCC now reviewing MITRE Report. Trying to make IDCCC more active, and expects working groups to "do something" (?).

- o Denny Parker suggested it was time for Cooperative Strategy to have formal bylaws, officers, and new name. MOTION: Claude Christensen moved that a committee be formed to draft new charter, bylaws, name. Dave Nystrom suggested Wayne Rohde, USGS-EROS, chair the committee. Approved.

- o MOTION: Group moved that FWS be appointed the new chair of the Cooperative Strategy for next year. Carried.

- o There was discussion on whether the Cooperative Strategy group should be concerned with public domain software in general or just the MOSS family. No action.

06/06/86
MOSS Conference

MANAGEMENT WORK GROUP
LIST OF ATTENDEES

Denny Parker	BLM-CSU
Duane A. Asherin	FWS-National Ecology Center, Fort Collins
G. Stephen Pitts	Oregon State University
Richard Marth	ETL
Brain Dealy	Earth Observation Satellite Co. (EOSAT)
Steve Wing	BLM -- Arizona
John Singlaub	BLM -- Washington Office
Clem E. Cearley	BIA -- Anadarko, Oklahoma
Steve Moore	BLM -- Grand Junction, Colorado
Wanda Hobart	Reclamation -- E & R 400 Denver, Colorado
R. Lee Lyons	BOR-APO (2276)
Michael A. McDonald	BOR-APO (2274)
Larry Handley	FWS -- Slidell, Louisiana
Bruce Keating	BLM -- Wyoming State Office
Bill White	USFS -- Fort Collins, Colorado
Bob Leopold	BLM -- Denver, Colorado
Lee Bender	Autometric, Inc.
Edwin Katlas	BLM -- Ukiah, California
Mike Dwyer	BLM -- Colorado State Office
Bill Bonner	BIA -- Office of Trust Responsibilities
Mon Yee	USDA/SCS -- Portland, Oregon
Bob Wright	BLM -- Oregon State Office
Gale TeSelle	USDA/SCS -- Washington
Claude Christensen	FWS-IRM
Ralph Marker	BLM-DSC
Dave Nystrom	USGS -- Reston, Virginia

SYSTEMS WORK GROUP SUMMATION

The Systems work group participants met and reviewed the results of the previous workshop. Although some recommendations have been acted upon, many of the previously identified issues remain. The Systems work group updated and resubmitted the following issues and recommendations.

A. Goals

Goal 1 - Discuss system configuration issues and make recommendations.

Goal 2 - Develop and coordinate short-term and long-term systems development and maintenance strategies.

Goal 3 - Establish a timeframe for implementation.

B. Configuration Issues

1. Maintenance of Compatibility

a. Describe existing operating systems that support MOSS, including VAX, HP, Data General, etc.

A survey of where we are in moving MOSS to operating systems other than Data General was requested. This was seen as an integral part of the compatibility question. (3 months)

b. Define the baseline configuration of MOSS within various operating systems, with priority to Data General.

The concept is to have standard configuration tape for each operating system to ease the problems of integrating an operating system with MOSS. This will be a time saver, with multiple installations. (The conversion to PRIME under PRIMOS establishes a baseline for Department of the Interior users.)

c. Investigate the development of a MOSSGEN tape that keys off the system configuration.

This would allow an installation to dump the operating system and then MOSSGEN and be completely operational, eliminating the tedious task of knitting everything together. MOSSGEN may include link files, operating system commands, etc. (9 months)

d. Review the ELAS software distribution process.

The ELAS software distribution process was noted as being very efficient with wide coverage. It was suggested that the ELAS system serve as a model for MOSS and other public domain software distribution systems. (9 months)

e. Define baseline versions of sysgens for operating systems for each MOSS host.

This would mean expanding recommendation 3 to include operating systems. (24 months)

f. Maintain separate versions of MOSS and sysgens for 32-bit, 16-bit, and virtual memory systems.

This is not meant to restrict MOSS capabilities to the lowest common denominator; documented variations will still be allowed within each group. This will encourage more standardization of the less esoteric functions of MOSS. (FY 87)

g. Develop a central distribution center for software.

Location and process may be agency-centered or other as options arise. This is designed to ensure all software updates and documentation are distributed thoroughly and quickly. This distribution method may be based on the process described in item d above. (FY 87)

2. Versions of MOSS

a. Adopt a policy of striving toward a unified MOSS by 1989.

Although a "one MOSS" is neither desirable nor achievable, a major portion of the software should be standardized across the many installations. Even though new applications and software routines are encouraged, an effort at directing, documenting, and distributing enhancements is needed. (1989)

b. Define a baseline version of MOSS.

There were 17 different names for MOSS at the Third National Users Workshop. It was felt there should be one standard version of MOSS that all alterations and enhancements would be gauged against and that would be the same at each installation. This need not encompass the entire software; only certain main modules of the program would be affected. (1 month)

c. Maintain a record of system deviations from the baseline MOSS.

This would allow users to see what other users are doing to get the most out of the software. This will also create a pool of "add-ons" or options to choose from. (2 months)

d. Produce a short document describing different MOSS versions.

This would be the method of describing the baseline that exists and the agency-specific deviations from that baseline. (9 months)

3. Subsystems of MOSS

a. Improve the development and maintenance support for data entry subsystems.

The documentation, development, and support of data entry subsystems was deemed inadequate. More training and better documentation are very important. Technical support of specific subsystems (AMS, ADS, etc.) has become more important as more installations have in-house data entry operations. (1 month)

b. Address the use of the USGS Digital Line Graph or Defense Department Standard Linear Format.

A standard digital map needs to be defined. If a single format is used consistently, compatibility between different systems would be enhanced. (The Federal Geographic Data Exchange Format is being evaluated by several federal agencies.)

c. Develop training for individual operating systems at MOSS sites.

Training may duplicate support services offered by the operating system vendor. (6 months)

d. Address the development of a generic reformatting program for inclusion in MOSS.

A command within MOSS that reformats any input file into MOSS format would be useful. (6 months)

e. Expand the arc/node design study to include capabilities of subsystems.

The USGS design study should be extended to include studies of the input and output subsystems (AMS, ADS, MAPS, COS, Projections). (9 months)

f. Develop a characteristics matrix for each subsystem.

Such a matrix would allow selections from the "subsystem menu" that best fit the requirements of a needs assessment (AMS, ADS, MAPS, COS, Projections). (9 months)

g. Make small volume digitizing capability available to remote users.

The difficulty of running two communications lines (terminal and tablet) over one communications link needs to be addressed. (12-18 months)

h. Establish training sessions for subsystems.

Many subsystems of MOSS have become very large and sophisticated. As operators become more specialized in plotting, digitizing, or analysis, training sessions on specific subsystems is warranted. (FY 86)

i. Develop an interface to existing DBM subsystems.

The need for more sophisticated data base management functions has become apparent. These types of subsystems operate independently from MOSS but allow easy communications between the two systems. (FY 87)

j. Develop public domain DBMS for MOSS.

The value of public domain software for bringing out the creativity of users is noted. Applying user-driven development pressure (vs market pressure) to a data base management system is seen as desirable, as is the significant increase in number of users that may obtain the low-cost or no-cost software. (FY 90)

4. Hardware

a. Isolate machine dependencies (word size) and operating system dependencies (virtual memory).

b. Provide training on operating systems.

Training on generating MOSS-specific operating systems is desirable. A much noted problem of MOSS users is file and space management; operating system training may help to alleviate these problems. (6 months)

c. Ensure the completion of the FWS-BLM procurement contract award.

The results of a successful procurement will be felt further than the new installations themselves. This action will help ensure the survival and spread of GIS technology at many different levels of resource management, both government and private. We often find ourselves in uncertain funding situations. This goal must be attained as soon as possible. (The Department of the Interior contract was awarded to PRIME in June 1986.)

d. Implement ANSI FORTRAN 77.

The move to an ANSI standard language will improve the "probability" of MOSS to different systems. (The award to PRIME included conversion to PRIMOS using FORTRAN 77.)

e. Develop machine independence for MOSS peripherals.

Many users can testify to the problem of the host-peripheral interface. Much time could be saved with device-independent software, coupled with operating system training. (FY 87)

5. File and Space Management

a. Investigate advanced data technology and storage, e.g., data compression techniques and optical digital disks.

Since we have begun to use the word gigabyte so frequently in our description of data bases, it is necessary to address efficient, affordable gigabyte data storage. Optical disk technology has been applied to audio and visual digital recordings with a high degree of technical success. Master data bases could be stored on optical disk and provide benefits analogous to microfiche use in libraries. The development of a read/write optical disk would revolutionize data storage. (6 months)

b. Establish and publish file management guidelines.

Information concerning file management, backup procedures, reformatting, etc., needs to be distributed to users. Special attention to space considerations is requested. (6 months)

c. Investigate single data base structure.

A single data base structure used across all types of public domain systems would enhance data compatibility. (9 months)

d. Develop a flexible archiving/restoring algorithm.

Since archiving in space management is important, the possibility of creating a one- or two-command procedure (dependent/operator-independent archiving) was proposed. This procedure would allow a file that was left inactive for a certain period of time to be archived automatically. Some requested a time interval of 5 minutes before archiving. (21 months)

e. Enhance data file indexing.

A method of searching for data other than listing map names was requested. Projects containing 80 quad maps and 50 workfile maps can be tiresome to list. (12 months)

f. Implement system changes to make data storage more efficient.

The systems subgroup felt that the resolution of file and space management problems should occur by FY 87 at the latest. (FY 87)

g. Apply RDBMS to file management systems, including graphics plot files.

There is a demand for a relational data base manager that is linked to the plot files. Editing from either a digitizing tablet or a terminal would be reflected automatically in associated data bases. (FY 87)

C. Coordination

1. The Management Steering Committee needs to address . . .

   - Creation of a central information center. (3 months)
   - Sites to distribute publications and software. (4 months)

2. The Systems subgroup will review the results of its work before giving them to the Management Steering Committee. (2 months)

3. A Technical work group needs to be established and should meet quarterly. This group should address the issues of modular development, standard interfaces, "decoupled" system functions, and configuration management.

4. The Management Steering Committee will decide who will be in the Technical work group. (3 months)

5. User agencies should be polled for MOSS development plans as a guide for further development. (5 months)

6. Significant developments of or enhancements to MOSS should be frozen until after the Design Study is complete and the Management Steering Committee has reviewed the results. (6 months)

7. A quarterly MOSS bulletin/newsletter/memo/flyer/paper, etc., should be created to publish tips, new applications, and solutions to problems. The use of an electronic bulletin board system should be explored. (6 months)

8. A central information center should be created for facilitating information transfer for MOSS and subsystems. Possible coordination centers are universities (e.g., Colorado State University, University of Missouri), federal agencies (e.g., BLM Service Center, USGS EROS Data Center), or contracted private organizations.

D. Management Summary

The following are recommendations from the Systems subgroup to the Management subgroup for near-term action:

1. Establish an information center to collect information for distribution.

2. Establish a distribution center to distribute publications and software.

3. Establish a Technical work group with representation from each concerned agency to support the Management Steering Committee.

4. Address the use of Digital Line Graph or Standard Linear Format as a common data format. This action requires coordination with the IDCCC and other groups. (The Federal Geographic Data Exchange Format is being evaluated by several federal agencies.)

5. Ensure that the FWS-BLM contract award is completed in FY 85, with procurement continuing through FY 91. (The Department of the Interior contract was awarded to PRIME in June 1986.)

Appendixes

APPENDIX A--LIST OF WORKSHOP PARTICIPANTS

1. BOB ADER
BUREAU OF LAND MANAGEMENT, DFC
BLDG. 50, D-150 P.O. BOX 25047
DENVER, CO 80225-0047

2. DANIEL ALBERTS
AUTOMETRIC, INC.
5205 LEESBURG PIKE, SKYLINE 1
FALLS CHURCH, VA 22041

3. JAMES ALM
BUREAU OF LAND MANAGEMENT
324 S. STATE #301
SALT LAKE CITY, UT 84111-2203

4. NORMAN AMES
306 E. 18TH #27
CHEYENNE, WY 82001

5. CLIFFORD ANABLE
BUREAU OF INDIAN AFFAIRS
WHITERIVER, AZ 85941

6. KEN ANDRESON
BUREAU OF LAND MANAGEMENT, DFC
BLDG. 50, D-150 P.O. BOX 25047
DENVER, CO 80225-0047

7. DUANE ASHERIN
U.S. FISH AND WILDLIFE SERVICE
2627 REDWING RD.
FORT COLLINS, CO 80526

8. LARRY BAGWELL
TGS TECHNOLOGY, INC.
P.O. BOX 28J 13111 W. ALAMEDA
LAKEWOOD, CO 80228

9. LOWELL BAHNER
COMPUTER SCIENCES CORP.
410 SEVERN AVE., SUITE 110
ANNAPOLIS, MD 21403

10. ROBERT BARACKER
BUREAU OF INDIAN AFFAIRS
P.O. BOX 368
ANADARKO, OK 73005

11. TERRY BARNEY
UNIVERSITY OF MISSOURI
235 ELECTRICAL ENGINEERING
COLUMBIA, MO 65211

12. LEE BENDER
AUTOMETRIC, INC.
5205 LEESBURG PIKE SUITE 1308
FALLS CHURCH, VA 22041

13. ROBERT BEWLEY
BUREAU OF LAND MANAGEMENT
P.O. BOX 6770
ALBUQUERQUE, NM 87197

14. KENT BIDDULPH
BUREAU OF LAND MANAGEMENT
324 SOUTH STATE
SALT LAKE CITY, UT 84111

15. BILL BONNER
BUREAU OF INDIAN AFFAIRS
730 SIMMS ST.
GOLDEN, CO 80401

16. JEFF BOOTH
US FISH & WILDLIFE
1825 VIRGINIA AVE.
ANNAPOLIS, MD 21401

17. SCOTT BRADSHAW
BIA-ALBUQUERQUE AREA OFFICE
BR. OF FORESTRY BOX 8327
ALBUQUERQUE, NM 87198

18. JOHN BRECKENRIDGE
BLM-DOI
P.O. BOX 1828
CHEYENNE, WY 82003

19. ERIK BREKKE
BUREAU OF LAND MANAGEMENT
P. O. BOX 1470
CANON CITY, CO 81212

20. RONALD W. BUHMANN
NOAA NATL. GEOPHYSICAL DATA CT
325 BROADWAY (E/GC1)
BOULDER, CO 80303

21. DIANE BURGESS
BUREAU OF INDIAN AFFAIRS
1425 N.E. IRVING
PORTLAND, OR 97232

22. MARK CALAMIA
BUREAU OF LAND MANAGEMENT, DFC
BLDG. 50, D-150 P.O. BOX 25047
DENVER, CO 80225-0047

23. MIKE CALLAHAN
USGS/NATIONAL MAPPING DIVISION
12201 SUNRISE VALLEY DR.
RESTON, VA 22092

24. PATRICIA CAPRON
BUREAU OF LAND MANAGEMENT
2515 WARREN AVE.
CHEYENNE, WY 82001

25. MIKE CARSELLA
TGS TECHNOLOGY, INC.
P.O. BOX 28J 13111 W. ALAMEDA
LAKEWOOD, CO 80228

26. CLEM CEARLEY
BUREAU OF INDIAN AFFAIRS
P.O. BOX 368
ANADARKO, OK 73005

27. EDGAR CHAPMAN
U.S.D.A. - WASHINGTON D.C.
12324 TRIPLE CROWN RD.
GAITHERSBURG, MD 20878

28. LLOYD CHAPMAN
OREGON DEPT./LAND CONSERVATION
1175 COURT ST. N.E.
SALEM, OR 97310

29. MARY CHAVEZ
BUREAU OF LAND MANAGEMENT
P.O. BOX 1449
SANTA FE, NM 87504

30. CHARLES CHESNEY
GIS TUTOR
4485 LOCH ALPINE DR. WEST
ANN ARBOR, MI 48103

31. CLAUDE CHRISTENSEN
U.S. FISH AND WILDLIFE SERVICE
18TH & C ST. N.W. RD. 859
WASHINGTON, DC 20240

32. WILLIAM CLERKE
USDA FOREST SERVICE
1720 PEACHTREE RD.
ATLAUTD, GA 30366

33. ANNABEL CLIFFORD
LOS ALAMOS NATIONAL LABORATORY
BOX 1663 MAIL STOP M701
LOS ALAMOS, NM 87545

34. DENNIS COLARELLI
TGS TECHNOLOGY, INC.
P.O. BOX 28J 13111 W. ALAMEDA
LAKEWOOD, CO 80228

35. DAVID CULLEY
TGS TECHNOLOGY, INC.
P.O. BOX 28J 13111 W. ALAMEDA
LAKEWOOD, CO 80228

36. DALE CUMMINS
BUREAU OF LAND MANAGEMENT
1037 20TH ST.
DENVER, CO 80202

37. BRIAN DEALY
EARTH OBSERVATION SATELLITE CO
4300 FORBES BLVD.
LANHAM, MD 20705

38. TOM DEJONG
STATE UNIVERSITY UTRECHT
HEIDELBERGLAAN 2
UTRECHT, HOLLAND,

39. BARBARA DUGGAN
TGS TECHNOLOGY, INC.
13111 W. ALAMEDA PKWY, BOX 28J
LAKEWOOD, CO 80228

40. CHARLES DULL
USDA FOREST SERVICE
3620 I85NE RM. 2003
DUROVILLE, GA 30340

41. MIKE DWYER
USDI-BUREAU OF LAND MANAGEMENT
2020 ARAPAHOE ST.
DENVER, CO 80202

42. FRANK D`ERCHIA
USFWS
1011 E. TUDOR RD.
ANCHORAGE, AK 99503

43. GERRY EDLER
BUREAU OF LAND MANAGEMENT, DFC
BLDG. 50, D-150 P.O. BOX 25047
DENVER, CO 80225-0047

44. JOHN ESTES
UNIVERSITY OF CA/SANTA BARBARA
DEPARTMENT OF GEOGRAPHY
SANTA BARBARA, CA 93106

45. TRACEY FEAGAN
TGS TECHNOLOGY, INC.
13111 W. ALAMEDA PKWY, BOX 28J
LAKEWOOD, CO 80228

47. PATRICK FMADIGON
BUREAU OF LAND MANAGEMENT
DENVER SERVICE CENTER
DENVER, CO 80225

49. HAROLD FORSEE
DEPARTMENT OF INTERIOR
WASHINGTON D.C., 20240

51. KEITH FRANCIS
BUREAU OF LAND MANAGEMENT
DENVER FEDERAL CENTER
DENVER, CO 80225

53. ROBIN GEBHARD
USFWS
9720 EXECUTIVE CENTER DR.
ST. PETERSBURG, FL 33702

55. MICHAEL GOLDBERG
INFORMATION ANALYSIS FACILITY
NASA/GODDARD SPACE FLIGHT CTR.
GREENBELT, MD 20771

57. ERIC GREENQUIST
BUREAU OF LAND MANAGEMENT
P. O. BOX 119
WORLAND, WY 82401

59. KATHERINE GRIFFIN
US ARMY
P.O. BOX 4005
CHAMPAIGN, IL 61820

61. DON HALL
CSU BUREAU OF INDIAN AFFAIRS
2627 REDWING RD. C/0 USF&WS
FORT COLLINS, CO 80526

63. RICHARD HANSEN
UNIVERSITY OF MINNESOTA
219 HODSON HALL
ST. PAUL, MN 55108

65. LODEWIJH HAZELHOFF
STATE UNIVERSITY UTRECHT
HEIDELBERGLAAN 2
UTRECHT, HOLLAND,

67. GEORGE HEINE
BUREAU OF LAND MANAGEMENT, DFC
BLDG. 50, D-150 P.O. BOX 25047
DENVER, CO 80225-0047

46. MIKE FIEBACH
TGS TECHNOLOGY, INC.
P.O. BOX 28J 13111 W. ALAMEDA
LAKEWOOD, CO 80228

48. JACK FORDHAM
BUREAU OF LAND MANAGEMENT, DFC
BLDG. 50, D-150 P.O. BOX 25047
DENVER, CO 80225-0047

50. EUGENE FOSNIGHT
U.S. GEOLOGICAL SURVEY
MUNDT FEDERAL BUILDING
SIOUX FALLS, SD 57198

52. MIKE GARRETT
BUREAU OF LAND MANAGEMENT, DFC
BLDG. 50, D-150 P.O. BOX 25047
DENVER, CO 80225-0047

54. DOUG GLADWIN
U.S. FISH & WILDLIFE SERVICE
2627 REDWING RD.
FORT COLLINS, CO 80526

56. ROBERT GREEN
BUREAU OF LAND MANAGEMENT, DFC
BLDG. 50, D-150 P.O. BOX 25047
DENVER, CO 80225-0047

58. STEVEN GREGONIS
BUREAU OF LAND MANAGEMENT
2020 ARAPAHOE ST.
DENVER, CO 80205

60. TIM HAITHCOAT
UNIVERSITY OF MISSOURI
235 ELECTRICAL ENGINEERING
COLUMBIA, MO 65211

62. LAWRENCE HANDLEY
U.S. FISH & WILDLIFE
1010 GAUSE BLVD.
SLIDELL, LA 70458

64. PAUL HARDER
DBA SYSTEMS, INC.
11781 LEE JACKSON MEMORIAL HWY
FAIRFAX, VA 22033

66. JOHN HEASLEY
U.S. FISH & WILDLIFE SERVICE
2627 REDWING RD.
FORT COLLINS, CO 80526

68. WANDA HOBART
BUREAU OF RECLAMATION
P.O. BOX 25007
DENVER, CO 80225

69. ERIC HOLM
U.S. GEOLOGICAL SURVEY
MUNDT FEDERAL BUILDING
SIOUX FALLS, SD 57198

71. CHARLES HOUGHTEN
U.S. FISH & WILDLIFE SERVICE
2800 COTTAGE WAY, ROOM W2143
SACRAMENTO, CA 95825

73. DON HUNTER
U.S. FISH & WILDLIFE SERVICE
2627 REDWING RD.
FORT COLLINS, CO 80526

75. ROBERT ITAMI
UNIVERSITY OF ARIZONA
BSE 325
TUCSON, AZ 85721

77. KATHIE JEWELL
BUREAU OF LAND MANAGEMENT
P. O. BOX 36800
BILLINGS, MT 59107

79. RICHARD JOLLEY
BUREAU OF LAND MANAGEMENT
1037 ARAPAHOE
DENVER, CO 80202

81. SOL KATZ
BUREAU OF LAND MANAGEMENT, DFC
BLDG. 50, D-150 P.O. BOX 25047
DENVER, CO 80225-0047

83. PHILIP KILKUS
BUREAU OF LAND MANAGEMENT
3080 EAST MAIN
CANON CITY, CO 81212

85. LISA KLAPWYK
BUREAU OF LAND MANAGEMENT
P.O. BOX 2965
PORTLAND, OR 97208

87. SARA KOCHER
UNIVERSITY OF ARIZONA
BSE 325
TUCSON, AZ 85721

89. DON LUSE
BUREAU OF INDIAN AFFAIRS
316 N. 26TH ST.
BILLINGS, MT 59101

91. STEPHEN MANNING
MORRISON-KNUDSEN ENGINEERS INC
1700 BROADWAY, SUITE 1600
DENVER, CO 80290

70. COLIN HORMAN
BUREAU OF LAND MANAGEMENT
1695 SPRUCE ST.
RIVERSIDE, CA 92507

72. TERRY HOWEY
LOUISIANA DEPT. NATIONAL RES.
BOX 44487
BATON ROUGE, LA 70804-4487

74. JOY IKELMAN
NAT'L OCEANIC & ATMOSPH. ADMIN
CODE EGC1, 325 BROADWAY
BOULDER, CO 80303

76. ELDON JESSEN
USGS, NAT'L MAPPING DIVISION
MS 510, DEN.FED.CTR, BOX 25046
DENVER, CO 80225

78. GREGG JOHNSON
TGS TECHNOLOGY, INC.
P.O. BOX 28J 13111 W. ALAMEDA
LAKEWOOD, CO 80228

80. EDWIN KATLAS
BUREAU OF LAND MANAGEMENT
555 LESLIE ST.
UKIAH, CA 95482

82. BRUCE KEATING
BLM-DOI
P.O. BOX 1828
CHEYENNE, WY 82003

84. JOHN KINEMAN
NATL ENVIRONMENTAL SATELLITE
NOAA/NGDC (E/GC1) 325 BROADWAY
BOULDER, CO 80303

86. ROBERT KLAVER
USDI BUREAU OF INDIAN AFFAIRS
P.O. BOX A
PABLO, MT 59855

88. GEORGE LONG
BUREAU OF LAND MANAGEMENT
1280 INDUSTRIAL AVE.
CRAIG, CO 81625

90. RICHARD LYONS
BOR-APO
23636 N. 7TH ST. BOX 9980
PHOENIX, AZ 85068

92. RALPH MARKER
BUREAU OF LAND MANAGEMENT, DFC
BLDG. 50, D-150 P.O. BOX 25047
DENVER, CO 80225-0047

93. RICHARD MARTH
U.S. ARMY ENGR. TOPO. LAB
ATTN ATL-GF-IV (RICHARD MARTH)
FORT DELVOIR, VA 22060-5546

94. DAN MARTIN
BUREAU OF LAND MANAGEMENT, DFC
BLDG. 50, D-150 P.O. BOX 25047
DENVER, CO 80225-0047

95. FRED MARTINSON
BUREAU OF LAND MANAGEMENT, DFC
BLDG. 50, D-150 P.O. BOX 25047
DENVER, CO 80225-0047

96. MICHEAL MCDONALD
DOI-BOR
23636 N. 7TH ST. BOX 9980
PHOENIX, AZ 85302

97. WILLIAM MCFARLAND
UNIVERSITY OF MISSOURI
235 ELECTRICAL ENGINEERING
COLUMBIA, MO 65211

98. RANDY MCKINLEY
TGS TECHNOLOGY, INC.
P.O. BOX 28J 13111 W. ALAMEDA
LAKEWOOD, CO 80228

99. GRETCHEN MEYER
BLM-DOI
P.O. BOX 1828
CHEYENNE, WY 82003

100. TERRY MITCHELL
BLM-DOI
P.O. BOX 1828
CHEYENNE, WY 82003

101. CAROL MLADINICH
USGS, NAT'L MAPPING DIVISION
MS 510, DEN.FED.CTR, BOX 25046
DENVER, CO 80225

102. STEVE MOORE
BUREAU OF LAND MANAGEMENT
764 HORIZON DR.
GRAND JUNCTION, CO 81506

103. BRUCE MORSE
AUTOMETRIC, INC.
2629 REDWING RD. #340
FORT COLLINS, CO 80525

104. JOHN MYERS
UNIVERSITY OF MISSOURI
235 ELECTRICAL ENGINEERING
COLUMBIA, MO 65211

105. HARRY NIEDZWIADEK
AUTOMETRIC, INC.
5205 LEESBURG PIKE SUITE 1308
FALLS CHURCH, VA 22041

106. TOM NIEMEIER
BUREAU OF LAND MANAGEMENT, DFC
BLDG. 50, D-150 P.O. BOX 25047
DENVER, CO 80225-0047

107. DAVID NYSTROM
USGS
521 NATIONAL CENTER
RESTON, VA 22207

108. JAMES ORWIN
BUREAU OF INDIAN AFFAIRS
COLVILLE INDIAN AGENCY
BOX 111, NN WA

109. THOMAS OWENS
COLORADO STATE UNIVERSITY
COLORADO STATE FOREST SERVICE
FORT COLLINS, CO 80523

110. DENNY PARKER
COLORADO STATE UNIVERSITY
DEPT. OF WILDLIFE
FORT COLLINS, CO 80523

111. CRAIG PATTERSON
WYOMING GAME & FISH DEPT.
5400 BISHOP BLVD.
CHEYENNE, WY 82002

112. KIM PAULSELL
BUREAU OF RECLAMATION
23636 N. 7TH ST. BOX 9980
PHOENIX, AZ 85068

113. SHELLY PEELE
BLM-DOI
P.O. BOX 1828
CHEYENNE, WY 82003

114. JOE PERRY
MINERAL MANAGEMENT SERVICE
3301 N. CAUSEWAY BLVD.
EBTAIRIE, LA 70002

115. G. STEPHEN PITTS
DEPT. OF GEOGRAPHY/OREGON ST.
OREGON STATE UNIVERSITY
CORVALLIS, OR 97331

116. JANET POORMAN
BLM-GIS TECHNOLOGY
BLDG. 40
DENVER, CO

117. BARBARA PRIEST
BUREAU OF LAND MANAGEMENT
P.O. BOX 2965
PORTLAND, OR 97208

119. VERNON RULLI
BUREAU OF LAND MANAGEMENT
BOX 1828 MAIL STOP 924
CHEYENNE, WY 82003

121. STEVE RUSSELL
TGS TECHNOLOGY, INC.
P.O. BOX 28J 13111 W. ALAMEDA
LAKEWOOD, CO 80228

123. WILLIAM SCHWENING
US ARMY CORPS. OF ENGRS.
215 N. 17TH ST.
OMAHA, NE 68102-4910

125. EEPAK SEHGAL
CONFED. TRIBES OF WARM SPGS.
P. O. BOX C
WARM SPRINGS, OR 97761

127. BRUCE SHORT
USDA FOREST SERVICE
RED RIVER RT. 2 BOX 23G
ELK CITY, ID 83525

129. BRIAN SPEARS
BUREAU OF INDIAN AFFAIRS
P.O. BOX B, LAND OPERATIONS
WARM SPRINGS, OR 97761

131. DIANE STOCKTON
TGS TECHNOLOGY, INC.
P.O. BOX 28J 13111 W. ALAMEDA
LAKEWOOD, CO 80228

133. JOHN SZAJGIN
GEOSPATIAL SOLUTIONS
882 E. LAUREL AVE.
BOULDER, CO 80303

135. WENDY TETLEY
BUREAU OF LAND MANAGEMENT, DFC
BLDG. 50, D-150 P.O. BOX 25047
DENVER, CO 80225-0047

137. ROBERT TURNER
LOS ALAMOS NATL. LABORATORY
ENG-11 MS M701
LOS ALAMOS, NM 87545

139. BERT VERMAY
STATE UNIVERSITY UTRECHT
HEIDELBERGLAAN 2
UTRECHT, HOLLAND,

118. DAWN RADTKE
U.S. FISH & WILDLIFE SERVICE
2627 REDWING RD.
FORT COLLINS, CO 80526

120. WILLIAM RUSH
BUREAU OF LAND MANAGEMENT
3948 DEVELOPMENT AVE.
BOISE, ID 83705

122. JERRY SCHAACK
BUREAU OF RECLAMATION
P.O. BOX 25007
DENVER, CO 80225

124. FRED SEAVEY
US FISH & WILDLIFE
1825 VIRGINIA AVE.
ANNAPOLIS, MD 21401

126. GARY SELNER
USGS
P.O. BOX 25046 MS 905 DFC
DENVER, CO 80225

128. JOHN SINGLAUB
BUREAU OF LAND MANAGEMENT
906 PREMIER
WASHINGTON, DC 20240

130. PATRICK STATA
WYOMING GAME & FISH DEPT.
5400 BISHOP BLVD.
CHEYENNE, WY 82002

132. ERIC STRAND
BUREAU OF LAND MANAGEMENT, DFC
BLDG. 50, D-150 P.O. BOX 25047
DENVER, CO 80225-0047

134. DAN TESKA
COLORADO STATE UNIVERSITY
COLORADO STATE FOREST SERVICE
FORT COLLINS, CO 80523

136. THOMAS THOMSON
UNIVERSITY OF MICHIGAN
430 E. UNIV. AVE.
ANN ARBOR, MI 48109

138. LAURA UMLAND
NICOLET NATIONAL FOREST
68 S. STEVENS ST.
RHINELANDER, WI 54501

140. DANIEL WEBSTER
TGS TECHNOLOGY, INC.
P.O. BOX 28J 13111 W. ALAMEDA
LAKEWOOD, CO 80228

141. PETER WESTCOTT
LEXIDATA
755 MIDDLESEX TURNPIKE
BILLERICA, MA 01865

142. DONNA WEYER
EDAW INC.
240 E. MOUNTAIN
FORT COLLINS, CO 80521

143. WILLIAM WHITE
USDA FOREST SERVICE, FPM/MAG
3825 E. MULBERRY
FORT COLLINS, CO 80524

144. BARB WHITE
U.S. FISH & WILDLIFE SERVICE
2627 REDWING RD.
FORT COLLINS, CO 80526

145. MICHAEL WHITING
USDA - SOIL CONSERVATION SERV.
2121-C 2ND ST.
DAVIS, CA 95616-4999

146. WALLACE WILLIAMS
MINERAL MANAGEMENT SERVICE
3301 N. CAUSEWAY BLVD.
EBTAIRIE, LA 70002

147. CAROL WILSON
BUREAU OF LAND MANAGEMENT, DFC
BLDG. 50, D-150 P.O. BOX 25047
DENVER, CO 80225-0047

148. STEVE WING
BUREAU OF LAND MANAGEMENT
3707 N. 7TH ST.
PHOENIX, AZ 85014

149. ROBERT WOODLEY
SMITHSONIAN ENVIR. RESEARCH
P.O. BOX 28
EDGEWATER, MD 21037

150. ROBERT WRIGHT
BUREAU OF LAND MANAGEMENT
P.O. BOX 2965
PORTLAND, OR 97208

151. EARL WYNNE
BUREAU OF INDIAN AFFAIRS
1425 N.E. IRVING
PORTLAND, OR 97232

152. BILL YEAGER
BUREAU OF LAND MANAGEMENT
3380 AMERICANA TERRACE
BOISE, ID 83702

153. MON YEE
USDA/SCS
511 N.W. BROADWAY, #547
PORTLAND, OR 97209

154. CARL ZULICK
BUREAU OF LAND MANAGEMENT, DFC
BLDG. 50, D-150 P.O. BOX 25047
DENVER, CO 80225-0047

APPENDIX B--WORKSHOP EVALUATION

What is your overall evaluation of the Workshop?

Excellent = 1   Good = 28   Satisfactory = 9   Unsatisfactory = 1

What did you most like about the Workshop?

- The opportunity for informal interaction between the users.
- Opportunity to hear what other user's major complaints and concerns were.
- Friendliness of the participants; close locality to Boulder area; low cost of registration.
- Getting people together who all use MOSS.
- Applications and systems presentations.
- Inter Bureau and Inter Agency participation.
- Workgroup Sessions, poster sessions, interaction.
- Enjoyed many of the papers.
- User group work session.
- Presentation of new developments in terms of hardware/software.
- Presentations, meeting environment (CSU Campus).
- User/manager work sessions.
- Poster exhibits.
- Format, examples of applications, expertise of attendees.
- Meeting people and making contacts, discovering what other agencies were doing with MOSS (applications).
- Interaction with MOSS users.
- Users workgroup session.
- Number of attendees.
- Poster sessions and workgroups.
- Opportunity to meet varied users either personally or through the papers.
- Topics were very good; enjoyed the applications part the most.
- The workshop for users to discuss problems.
- Meeting other users.
- Users' meetings on Weds and Thurs., papers presented.
- Users meeting.
- Inter-action with users, discussion of ideas outside fo the work groups.
- Presentations on MOSS applications.
- Liked paper presentations best.
- Applications presentations.
- Discussion of user applications.
- Contacts with MOSS user community.
- Facilities.
- Presentation of applications Users Group Discussions.
- User project work papers, user workgroup, individual interaction.

What would you most like to see changed for future workshops?

- Compress to 2 days and move to more central location. Change structure of session to more technical information about MOSS and workings of MOSS.
- Have a lunch banquet instead of evening banquet - so people from the area can attend easily; concurrent sessions; a MOSS - connected terminal on-site for training - a large video screen preferred.
- Actual practical examples of MOSS processing not end product analysis.
- Workshop workgroups.
- Start and finish on time - all speakers.
- Make sure speakers have enough time to present papers.
- More time needed for User Workshop.
- Moderators to be more aggressive about keeping speakers on time.
- Better scheduling on speakers.
- Keep on schedule. Fewer application papers unless they discuss their topics relative to methodology for using MOSS as a tool.
- Nothing.
- More control of speakers, Infocen sales pitch was totally out of line.
- No vendors to present paper.
- Time restrictions on presentations, introductions, and breaks.
- Locate closer to airport then begin earlier Monday.
- Keep to time schedule (speakers), fewer vendors, more MOSS applications - not ARC-INFO.
- Concurrent sessions with structured subject categories.
- More time for the presentations, moderator keeping the presentations and workshops flowing; more time for the work groups.
- Keep to schedules.
- Work groups need more time and should occur first in the week.
- Would like to see sales pitches disguised as presentations eliminated.
- Time needs to be kept more stringently. Some papers and their impact were lessened due to time constraints.
- More time for user work group, more time for speakers.
- More time for papers.
- Charter and affiliate with a formal MOSS Users' organization.
- Monitor time more closely for breaks and persons giving papers.
- Better facility, Systems group should meet after users group and discuss problems brought up by the users.
- Place a time restriction on presentations.
- Stay on schedule, allow sufficient time for users group.
- Less papers per session, Advanced preparation for workgroups - perhaps distribution of advanced materials to establish the agendas in advance of the workshop.
- Talks which concentrate on methods, not results; Publish papers prior to the workshop; Have tutorials for MOSS training running concurrently to technical sessions; Better snacks at tea time, decaffinated coffee & herb tea.
- Vendors stick to applications not sales during presentations.
- Fewer application papers.
- Presentations to smaller, more well-defined target audience rather than the whole group.

What would you most like to see changed for future workshops? (CONTINUED)

- Time control on presentations.
- Keep to schedule - don't wait for all to come in (inevitably they won't).
- More time for User work group.

What do you feel were the highlights of the Workshop?

- Banquet, applications papers, work group sessions in general specifically departmental position by Ed Forsee.
- The "Users work group meeting" on Wednesday. This meeting demonstrated to me the amount of confusion and disorganization that exists between and within agencies with GIS organizational issues. Until everybody stops "doing their own thing" and we get some organizational strategy in place, ADS-AMS-MOSS-COS will continue to flounder. Data input standards need to be developed for each theme to be used in the GIS. It has to be decided NOW whether this is to be done at the Federal, Department, Bureau, State, District, or resource area level. Presently in BLM this is being done at the state office level which means that theme content and attributes will vary widely from state to state. Projects that cross state lines will be delayed due to inconsistent data. In talking to people at this conference I got the impression that people are building GIS Data Bases by project with little thought given to planning a GIS Data Structure that will serve their Bureau or even their state in the long term.
- Work groups - however most people seem to confuse MOSS with GIS rather than understand MOSS is only one software package in GIS. Workshop should be renamed if it is going to continue to put emphasis on the whole system - Personnally I think it should include the whole GIS - not just MOSS.
- The User Group Discussion; the (few) well-presented applications sessions.
- Workshop work groups.
- Exhibits and posters.
- Very well prepared and presented papers.
- Papers, banquet.
- Discussion of common problems associated with MOSS procedures.
- Papers presenting new technologies in terms of hardware and software; Panel discussions on the technologies.
- Poster sessions, presentations, work group meetings.
- MOSS specific applications papers, work sessions.
- GIS applications presentations.
- MOSS enhancements/fixes.
- User application papers (Sol Katz!) and information gained on changes made to the MOSS Program.
- Sol Katz's presentation and Dr. Pickett's talk the 2nd day of the Users Group workgroup was productive.
- Work study sessions.
- Very useful overall.
- Jack Estes talk on training; Eric Greenquist and Erik Brekke wildlife talks; Sol Katz (need I say more?)
- I am always amazed at the number of new applications in MOSS and enjoy the papers explaining and demonstrating these.
- Papers.
- Users' meetings on Wednesdays and Thursdays, papers presented.

What do you fee were the highlights of the Workshop? (CONTINUED)

- People exchanging ideas and information.
- Sol Katz's presentation as well as the following presentation were right to the point and not drawn out.
- The papers, vending area, posters and finally getting the group solidified as a unit to present a united effort.
- Applications presentations, poster sessions, banquet.
- The jokes and tea breaks; lunch; user presentations.
- Users work group. Application presentations.
- Presentation of New Enchancements/establishing contact with users.

How did you first learn about this Workshop?

Brochure = 15 Personal contact = 22 Other = 4

Other = Poorly advertised.
Bruce Neating.
My boss felt this would be an appropriate activity for me since a colleague was planning to attend.
Previous workshops.

Please list the names and addresses of others in your organization who should receive advance notices of future workshops in this field.

- Director, Fish & Wildlife Service, 18th & C Street NW, Washington, D.C., 20240
- Richard Johnson & Jon Foster, Bureau of Land Management, Federal Center, Sacramento, CA.
- Dr. James O'Kelley, Chief, Branch of Applications USGS, 521 National Center, Reston, VA 22092.
- Craig Patterson, Pat Stuta, Bill Moris.
  Wyoming Game and Fish Department, 5400 Bishop Blvd, Cheyenne, WY 82001.
- Ron Ray, BLM- Arizona Strip Do, St. George, Utah.
- Assoc. State Director, Oregon State Office, PO Gox 2965, Portland, OR 92208.
- Paul Vetterick, BLM - Minerals Division, 825 NE Multnomah, Portland OR.
- Renee Duval - BLM, Worland District Office. Karla Swanson - BLM, Rock Springs, D.O. Steve Strenger - BLM, Rawlin, D.O.
- H. Ross Pywell, USFWS - N.W.I., 9720 Executive Center Dr., Ste. 101-Monroe, St. Petersburg, FL 33702.
- Jon Winemiller, 2575 Warren, Cheyenne WY 82001.
- Jack Sheffey, White River Res. Area, (BLM), Meeker, CO 81641.
- Sam McReynolds, ADP Coordinator, BLM 764 Horizon Dr., Grand Junction, CO 81501
  Grant Loomis, GIS Coordinator, BLM, Glenwood Springs, CO
- I have several addresses at home which I can mail to whoever is the appropriate person.

Please suggest topics you would like to have presented at future workshops:

- Some papers on management aspects of MOSS projects would be nice.
- "How to cure a "slice" and "chipping from a downhill lie."
- More applications on wildlife biology - archeology; a demonstration of new commands. A (basics) Beginners tutorial on MOSS - including history, etc.
- Training component, overview of different versions of MOSS in user community, provide method of sharing enhancements to MOSS Made by various users (Marcos, etc.)
- Discussion of equipment limits, costs and compatability.
- MOSS enhancements.
- Anticipated changes in software/hardware/equipment - if any.
- More specific strategies regarding the use of MOSS for different kinds of projects. Time involved, techniques or commands used to extract data. Skip or gloss over specific results since they are not that pertinent. Would like to see more emphasis of GIS's working with IBM PC's compatibles.
- Menu-MOSS-Post conversion capabilities Micro-MOSS.
- Coverage of new hardware installation, use problems. Oregon is preparing portable live demo of the "smart terminal" and "Intelligent cursor$_{tm}$" for next year and will offer that to the session.
- GIS applications.
- Methods of finding support, savings from MOSS use.
- MOSS user T-shirts! Network listing of users, and as always info on updates and changes to MOSS.
- Better review of fixes - updates - proposed enhancements etc.
- 1) Standards for Data Input.
  2) Data Base Management and combining systems ie:
  IHICS)
  IMAX)→ MOSS
- GIS applications in solid minerals work, specifically coal.
- More cultural resources obviously; one of two presenters did not show. Those two were my main reason for attending.
- Actual hands on demonstrations of MOSS problems with group brainstorming of problems.
- (Optional - perhaps during or after 5:00 registration) New Users' orientation Q & A/hands-on session/demonstration.
- Need to form MOSS Users' group before next workshop.
- Presentation by systems support group on new enhancements to MOSS which will be placed in new releases of MOSS.
- Coverage this year was better than previous, but wider next time would be better. Perhaps a little more "HOW TO" in applications.
- Expanded applications presentations, decreased work groups sessons.
- Reworking & formatting of the "AMS" menus.
- More application - specific presentations.
- Tutorials and training sessions [Trainer training, etc] New hardware additions - Non-standard applications.
- Data entry portion - ADS/AMS.
- 1) Other agencies/organizations using MOSS.
  2) Equipment developments.

The Workshop meeting facilities were:

Good = 22 Satisfactory = 12 Unsatisfactory = 1

Comments:

- Need different room layout for work groups.
- Chairs were uncomfortable.
- Too cold for prolonged sitting - extremely uncomfortable.
- Exit and entry of the room was impossible without disturbing the group - too cramped.
- Room seemed very cold all the time.
- Seating was uncomfortable after a certain time in those execrable buckets.
- Liked the closer feeling from MOSS 2 where we were all together.

The food service at the Workshop banquet was:

Good = 23 Satisfactory = 7 Unsatisfactory = 0

Comments:

- Could we possibly have a choice of chicken or fish, instead of just red meat?
- Some of us don't like well done meat.
- Speaker was excellent!
- Enjoyed banquet alot - food was fine and good chance to visit with others.
- Not enough refreshments to go around every time.
- Breaks were too short and short on coffee. College classroom was uncomfortable for all day meetings.
- Table setup could be neater, i.e. sugar etc. in nicer containers. More coffee should be supplied.

Additional comments and/or constructive suggestions:

- Fewer papers, more time spent in work groups.
- Separate out software presentations to a separate concurrent session.
- The organization did an excellent job! I appreciate the effort!!!
- Screen vendors presentations - limit time, prevent sales pitches if giving a paper.
- Keep things on time!
- Extend the length of the conference from 3 days to 4 days to allow for more time in workgroups, papers etc.
- No vendors on program; keep meeting on schedule! Keep presentations to strict 15 minute time limit! Moderators should be instructed to maintain the time limit!
- Extend workshop one day. Report/presentation demonstrating actual benefit derived by use of GIS - how do people benefit?
- Appreciate the effort of everyone and looking forward to the next one.
- Have an agenda set up in advance for the work group sessions. Would like a GTIC report.
- Liked having conference at CSU.
- Having refreshments at break was a good idea.

Additional comments and/or constructive suggestions: (CONTINUED)

- The meeting sessions disintegrated when we ran as much as an hour late. This is not fair to the later speakers or the audience. It did not appear that this meeting was geared to handle the attendance. Suggest a strict adherence to 15 min. rule be enforced. Would like to see a copy of the last workshop!
- Better planning is needed on the program. Moderators and facilitators need to take charge. Have concurrent sessions - although there is risk of discussions of interest conflicting you don't have to sit through topics of no interest. Registration was too much! Please accept these comments as constructive. In return I look forward to the next workshop.
- Continue the poster section and changes (to MOSS) updates, send out meeting notes and copies of papers. Have speakers identify what MOSS version they are using and on what equipment.
- Overall the session was a waste of time, with few real productive topics being covered that is of benefit to MOSS users or GIS development. Real emphasis should be on software development, GIS development-etc. We need specific enhancements. (Example-at the last workshop many software enhancements were identified such as arc/node architecture, but as yet there seems to be little if any work being done on these enhancements.
- MOSS is not GIS. MOSS Is a software package used to create a GIS alone with other packages. Separate GIS's are presently being created by many various users. Without a major planning and standardization effort now, we will be faced with massive re-formatting of data at some later date or mass re-digitizing of data according to new standards developed later. There seems to be a movement to change the workshop into an applications seminar. This is a move in the wrong direction. It should remain as a technical discussion of ADS-AMS-MOSS-COS (and GIS organizational issues within agency meetings).
- Feel there was not an adequate plan/commitment by management on this workshop's (and last workshop's) identified recommendations. Also failed to do what is probably the inevitable rewriting (re-coupling and standard interface re: systems subgroup 1986 workshop) of MOSS - when & how funded?
- More time is needed for presentations - 15 min. is not long enough - can have 15 min. presentations but allow 20 min. for transition/run-over/ questions, etc.
- Where are the managers? No State Directors or Regional Foresters. No agency power from Washington, D.C. How does the life of Jim Parker get a feel for your concern about MOSS?

  Speakers need to be better prepared. Familiar with equipment, dry run before formal presentation.
- Too many presentations were scheduled within a short time frame. Some time should be allotted for combining work groups for discussions on common issues - and for input on problems.
- CSU should be heavily considered for future site (permanent?) meetings. Campus facilities very well fit with workshop needs. Removes Feds from working environment. Denver site too oppressive. Session moderators at fault in not keeping speakers on time. Tracy & Barb - good job!

Additional comments and/or constructive suggestions: (CONTINUED)

- A good workshop, but I'm sure that this workshop took a lot of work on a lot of peoples parts with little or no recognition and lots of frustration. A possible consideration for future workshop would be using a management service to moderate, take minutes, etc. A well done job, Thanx.
- I noticed that managers "decide" whereas users were referred to as "proposing". And that these terms were applied to simultaneous events. Hence managers are deciding without users proposals. Users and managers both seemed frustrated. Suggestion: difficult situation because people bring "deciding" but all "proposing" and such ground rules being established in a large group session with "decisions" being made in large group at end would ease the feelings, even if decisions were only prioritizing of problems to be attached by managers. Users feel no control.
- 1) Send mail directly to mailing list, not to Directors or Officials in the organization.
  2) Limit time for each activity (or papers) and stick to it strictly. Before setting limits, make sure sufficient time for the activity is allowed.
- Since our agency does not use mapping at this time, I still found this meeting beneficial to our planning for this system. Time restrictions should be placed on speakers (ex. 12 minutes - speak, 8 minutes questions & setup.) This annual meeting is a great help for all those who work with MOSS, mapp, ADS, AMS & COS.
- More specific schedule for presentations (should help stay on schedule). More poster session presentations (to accompany applications presentations). Work groups seem to be ineffective - they either need a better focus or redefinitions. Perhaps presentations could be grouped by subject. Area: systems, management, applicatons, and run concurrently.
- This organization could collect specific application Data/Results which could be used by teaching groups as examples of use of GIS - a call for this type of participation could go out for next years meeting. Thank you for putting on this meeting. For next years meeting use Monday fuller - have a morning meeting - use Thursday.

DATE DUE

[illegible]

(Continued on reverse)

BLM LIBRARY
SC-324A, BLDG. 50
DENVER FEDERAL CENTER
P. O. BOX 25047
DENVER, CO 80225-0047